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STRIKING ENTOMOLOGICAL EVENTS OF THE LAST DECADE OF THE NINETEENTH CENTURY

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THIS is written from the view-point of an economic entomologist—one who studies insects with a view to their control.

Following very soon after the establishment of state agricultural experiment stations in the United States as the result of the so-called Hatch Act passed by the federal government in 1888 and the almost simultaneous founding of the Association of Economic Entomologists, there occurred four events which fixed the attention of the whole country upon the importance of entomological work. The first of these was the discovery of the gipsy moth in Massachusetts in 1889; the second was the discovery of the San José scale in the East in 1893; the third was the discovery of the Mexican cotton boll weevil in Texas in 1894, and the fourth was the discovery by Ross in 1898 of the carriage of malaria by Anopheles. The first three were events apparently then of importance to the United States only; the last was of great importance to all humanity.

THE GIPSY MOTH

It very often happens that injurious insects coming from abroad obtain a foothold in the United States in some way that we are not exactly able to explain. We may know in a general way that they have come in in the course of commerce in plants or plant products, as was undoubtedly the case with the Japanese beetle and the European corn borer, or in the straw packing about fragile imported packages, as may have been the case with the alfalfa weevil.

But with the gipsy moth it seems rather certain that it was brought over from Europe in the egg stage to assist in a scientific experiment that a French astronomer, employed in the Harvard Observatory, was carrying on in the cross-breeding of certain silk-producing caterpillars in the hope of establishing a race that would be resistant to the pebrine disease which was at that time threatening the destruction of the silk industry in France. This man, Leopold Trouvelot, imported egg-masses of the gipsy moth from Europe where this insect had long been known as a destructive enemy to forest trees. By some accident, the insects escaped from his laboratory and established themselves in waste land in Medford near his house. This was in 1869. He notified the scientific public, but nothing was seen of the gipsy moth, which remained, however, gradually increasing on this waste land until 1889 when a tremendous plague of

caterpillars almost overwhelmed the little town. The numbers were so enormous that the trees were completely stripped of their leaves; the crawling caterpillars covered the sidewalks, the trunks of the shade trees, the fences and the sides of the houses, entering the houses and getting into the food and into the beds. They were killed in countless numbers by the inhabitants, who swept them up into piles, poured kerosene over them and set them on fire. Thousands upon thousands were crushed under the feet of pedestrians, and a pungent and filthy stench arose from their decaying bodies. The numbers were so great that in the still, summer nights the sound of their feeding could plainly be heard, while the pattering of their excremental pellets on the ground sounded like rain. Valuable fruit and shade trees were killed in numbers by their work, and the value of real estate was very considerably reduced. So great was the nuisance that it was impossible, for example, to hang clothes upon the garden clothes-line, as they would become covered with the caterpillars and stained with their excrement. Persons walking along the streets would become covered with caterpillars spinning down from the trees. To read the testimony of the older inhabitants of the town, which was collected and published by a committee, reminds one vividly of one of the plagues of Egypt as described in the Bible.

During all this time the Medford people had been under the impression that the insect which they were fighting in their gardens was a native species, and they knew it simply as "the caterpillar" or "the army worm"; but in June, 1889, when the plague was at its height, specimens were sent to the Agricultural Experiment Station at Amherst, and were identified by Mrs. C. H. Fernald as the famous gipsy moth of Europe.

A town meeting was immediately called in Medford, and work against the insect was begun. The next year a state appropriation was made, and very active and intelligent investigations were carried on under continually increasing appropriations until 1901 when, unfortunately, just as the possible extermination of the species appeared to be in sight, the appropriations were stopped and were not renewed for four years. During those four years the insect increased and spread from an area of about 400 square miles to one of 4,000 square miles.

In 1905 the federal government was called in and since that time has made large appropriations annually.

When the fight was rebegun in 1905 it was realized that the opportunity for extermination was gone, and that all efforts should be based upon the ideas of control and prevention of spread. It is a pity that the state appropriations were interrupted in 1901. It is a pity that the federal government did not take hold at the start and make every effort to exterminate the pest while it was still confined to the vicinity of Medford. But the government did not do things of that sort at that time. Appropriations were small and hard to get. The economical New Englanders were tired of the expensive fight, and it is hard to blame them. Knowing what we do now, it would seem that the federal Bureau of Entomology might fairly be blamed for lack of foresight in not warning Congress and the other states of the great danger and in not appealing to Congress for funds with which to prosecute radical work. As I look back, the idea seems never to have occurred to us. It seemed to us a state matter which Massachusetts could handle if she would. There is no doubt that prior to 1901 large areas had been so carefully gone over by state forces that the gipsy moth was exterminated locally, and we argued that if this

could be done over a number of square miles it could be done over the 400 square miles then occupied by the insect.

All this is now, however, vain speculation. The insect has spread gradually, and for a very large part its commercial spread in great jumps has been prevented by quarantine and inspection. Such commercial jumps have occurred, however, in one case as far as Ohio, and in several cases in New York. All, however, have been discovered in time, and vigorous work has exterminated the insect, except in a large New Jersey outbreak which is only now being reduced to such an extent that successful extermination seems a matter of a very few years. This last case, by the way, was not a commercial jump, but undoubtedly a direct accidental importation from Europe.

But the other New England states have all been invaded, and all of them have passed legislation compelling community and individual work. The federal government has occupied itself along the boundary of spread in the effort to hold the pest in check. In the interior, the states have been supposed to control destructive outbreaks. At the present time both New York State and the federal government are holding it back along a line extending from Canada to Long Island Sound (virtually the valley of the Hudson River) which has been termed a "Hindenburg line."

Some years after the gipsy moth was discovered in Massachusetts another European pest, the brown-tail moth, was found to have been imported in its winter webs on rose bushes from Holland and to have become thoroughly established, and the study of this insect and its treatment was included with the gipsy moth work carried on by the state. The brown-tail moth, however, after a comparatively few years proved not to spread so rapidly as the gipsy moth, and to be so easily handled by the cutting and burning of its conspicuous webs during the winter time and moreover so readily attacked by parasites imported from Europe that it has ceased to be considered as a pest of the first importance.

The operations against these two insects, and especially the gipsy moth, constituted the largest and most continuously active work supported by legislative appropriations that the country had yet experienced. The cotton boll weevil work differed in the fact that the invaded states can hardly be said to have done their share financially, at least in comparison with the New England and bordering states.

The gipsy moth work has accomplished several notable things in addition to what in itself may be termed more or less of a feat, namely, keeping it all this time practically within the borders of the New England states. These other things are, first, a striking improvement in insecticides. The old Paris green, upon which farmers and fruit-growers had relied during the latter part of the last century, was found, in the ordinary solutions, to be ineffective against the gipsy moth. The vigorous caterpillars of this species, it was found, can consume with impunity almost ten times the quantity of arsenic that would kill any other caterpillar against which it had been used, and larger proportions of arsenic could not be used since the burning of foliage would result. In the course of the work of chemists employed by the State of Massachusetts, arsenate of lead was found to be effective and not injurious to foliage, and this substance has been used by the thousands of tons, not only in the work against the gipsy moth but in orchard work against the codling moth and many other insects.

The second result of the gipsy moth work was the enormous improvement of spraying machinery. In the spraying of

tall trees, spray nozzles were soon abandoned, and solid-stream nozzles substituted. The stream of poisoned water thrown up with great force from the powerful machine breaks into the requisite spray long before it reaches the tops of tall trees. All the features of the machines and of the hose were gradually improved, and it has of late been one of the marvels of applied entomology to see a spraying machine by the roadside in the mountainous regions of southern New Hampshire getting its supply of water from a roadside stream, and, through strong sectioned hose carried up over the top of hills of considerable size, spraying the trees on the other side of the hill, perhaps nearly a mile away.

In the course of the gipsy moth work entomologists found themselves able to carry out on a very large scale and for continuous years the importation of parasites of the gipsy moth and the brown-tail moth from Europe and from Japan. The funds at their disposal allowed the entomologists to make very careful studies of these parasites and of the general subject of parasitism among insects. While there has been nothing spectacular in the results of this side of the investigation, there can be no doubt that the importation of many species of these parasites and natural enemies has resulted in great good. A number of them have been established in this country, and the present condition of the woodlands of New England as contrasted with the conditions that existed twenty years ago is attributable in no small part, I believe, to the destruction of both gipsy moth and brown-tail moth by these imported species.

The country has been fortunate in the type of men connected with this work from the start. The fine volume published by the State of Massachusetts in 1896, which is a report of the work on the gipsy moth and was written by E. H. Forbush, field director in charge of remedial work, and C. H. Fernald, consulting entomologist, is a model of its kind. Dr. Fernald continued his active interest in the work as a consultant for many years. Mr. Forbush was active until the state appropriations stopped in 1901. When they were resumed in 1905 he was succeeded by A. H. Kirkland, a former student of Professor Fernald's, who grew up with the work and who proved to be an inspiring and efficient executive. Later the work was taken over by the state forester, but the great emergencies had passed, and little more was needed within the invaded states than more or less routine work.

Of the part that the federal Bureau of Entomology took in the work, it need only be stated that we entered upon it first in 1905, at the invitation of the State of Massachusetts, and that our efforts were confined for the first few years to the importation of European parasites and their care. Later the federal government began to make large appropriations to assist in the prevention of the further spread of the insect, and in the conduct of that work Mr. A. F. Burgess has shown himself to be most efficient and resourceful. He was aided in the quarantine features of the work by Mr. D. M. Rogers, a Massachusetts man, who had been associated with the project from the early days. These quarantine features constituted the first federal quarantine work against insects done in this country, antedating the establishment of the Federal Horticultural Board by several years.

The San José Scale

When Professor Comstock, in the summer of 1880, found *Aspidiotus perniciosus* in the Santa Clara Valley of California he was so impressed by the damage which it was doing that he had no hesitation in applying the specific name *perniciosus* to it, since, as he said:

> From what I have seen of it, I think it is the most pernicious scale insect known in this

> country; certainly I never saw another species so abundant as this is in certain orchards which I have visited. It is said to infest all the deciduous fruits grown in California, excepting peach, apricot and the black Tartarian cherry. It attacks the bark of the trunk and limbs as well as the leaves and fruit. I have seen many plum and apple trees upon which all the fruit was so badly infested that it was unmarketable. In other instances I have seen the bark of all the small limbs completely covered by the scales. In such instances the wood beneath the bark is stained red.

In his account he gave the insect the common name of "the pernicious scale"; the name "San José scale" seems to have originated in California, a term to which the citizens of San Jose have always objected.

The insect spread along the Pacific coast rather rapidly and was the occasion of much loss, but for years was confined to that part of the country.

The species was not known to Eastern fruit-growers until 1893. In August of that year Dr. Hedges, of Charlottesville, Virginia, discovered some curious spots on his favorite pears and sent them to Dr. Galloway, of the Department of Agricultur~~e, thinking that~~ they were a fungus disease of some kind. Dr. Galloway brought them to me, and I jumped from my chair in excitement on recognition of the fact that the San José scale was at last in the East. Men were sent at once to Charlottesville, and an effort was made, by the use of oil insecticides, to exterminate the outbreak. In the course of the next few months, however, scales were received from Maryland and Florida; and hence in the spring of 1894 an illustrated warning circular was sent out which resulted in the receipt of specimens from very many localities, and it was found that the dread orchard pest was rather thoroughly established throughout the Eastern states, largely from the fact that two firms of nursery dealers in New Jersey had imported infested stock from California, that their nurseries had become well infested and that the stock which they had sold here and there and everywhere had carried the scourge.

The announcement of these facts aroused the most intense interest among fruit-growers everywhere. The entomologists of the different states at once began investigations and experimental work. The sale of nursery stock had become so great an industry during recent years, and the multiplication of this scale insect is so rapid, that, without another introduction of the scale from California, the products of two introductions in the East had in six years been spread through portions of almost every one of the Eastern and Middle states. Not only the economic entomologists, but the agricultural and horticultural societies, the agricultural journals and the state organizations became aroused, and in the next few years the literature relating to this insect became enormous. Within five years its bibliography comprised several hundred titles of permanent record, and several thousand articles had appeared in ephemeral publications. It had occupied the attention of nearly every meeting of farmers and fruit-growers that had been held in the Eastern states, from the village clubs to the great state horticultural or agricultural societies. It had been the exciting cause of a national convention of fruit-growers, farmers, entomologists and nurserymen. It had been the subject of legislation in sixteen states of the union, and its suppression was the principal object of two bills before Congress. Thus the entomologist had become a person of much importance.

But this was not all. On February 5, 1898, the emperor of Germany issued a decree prohibiting the admission of American fruits and living plants into Germany. A day or so later a shipment of California pears arrived at the port of Hamburg and was refused admittance. The fact was telegraphed to

American newspapers and there was much excitement both in horticultural and in official circles. General interest was created by the more or less sensational articles published.

For some days there was no knowledge in this country of the wording of the decree, and beyond the fact that it was understood that the introduction of injurious insects from America was feared, no reason for its promulgation could be assigned. The general impression seemed to be that the decree was issued at the instigation of the agrarian party in Germany and that it was to be considered as a retaliatory measure against the United States for certain tariff legislation by this country. All the early articles published in the United States protested vigorously against the enactment, and insisted that there was no ground for it, since the danger to Germany from American insect pests was purely imaginary.

Californians were particularly indignant, since it was a shipment of California pears that had been refused. Interviews with Congressional representatives of that state, published in Washington, stated that California especially prided herself on the cleanness of her fruit and upon the vigorous measures which for years she had taken to prevent the introduction of injurious insects within her boundaries. It was reported in the newspapers that vigorous diplomatic correspondence between the two governments ensued and that Ambassador Andrew D. White had been instructed to protest energetically against the edict and to endeavor to secure a modification of its terms.

It was not long, however, before the text of the imperial decree became known, and it was then found that the particular insect aimed at was the San José scale. When Ambassador White, at the instruction of Secretary of State Judge William R. Day, called on the foreign minister, Von Bülow, in Berlin, the latter sent a clerk for certain documents and handed the American ambassador a bulletin on the San José scale that had been published in 1896 by the Department of Agriculture at Washington and that contained all the facts concerning the destructiveness of the insect and its menace to Eastern orchards. (Possibly the fact that Dr. White, who had been president of Cornell University, discovered that the bulletin had been written by one of his own former students may have given an added assurance to its soundness.)

The action of Germany immediately called the attention of other nations to the danger which similarly threatened them. On March 18, 1898, Canada passed a prohibitory law known as the "San José Scale Act." A month later the government of Austria-Hungary issued a decree simultaneously at Vienna and Budapest prohibiting the importation into that country from America of all living plants. Holland and Sweden sent experts to the United States to make a study of the situation.

Thus the San José scale not only was the cause of a very great arousing of interest in entomological matters in the United States, but also promoted international quarantines on a very large scale.

From the action that foreign governments took at this time we may date the beginning of the agitation in this country to provide for our own protection against foreign importations, which, delayed for years largely by the lobbying of the very interests which ought to have been most friendly to its passage, was finally enacted into the federal horticultural law of 1912.

While the United States has thus perhaps ultimately profited by the whole experience, there is one lesson which she might have gained but which she does not seem to have learned. Germany at

that time had an agricultural expert attached to her embassy at Washington. I think that it was Count Beno von Hermann. He was a charming young man, well posted and a ready talker. I myself handed him in my office one day when he called a copy of the bulletin that brought about all the trouble for the United States and which was afterwards shown to Ambassador White by Foreign Minister Von Bülow. The United States should have had, and should have, men of similar ability in agricultural lines attached definitely as "agricultural attachés" to its principal foreign offices. This was done once, in the case of C. W. Stiles, who was stationed in Berlin for a time when the subject of trichinosis in German meats was under dispute, but it has never become a practice.

At the present time the San José scale is not the terrible orchard pest that in 1898 we feared it would become. This does not mean that the alarm excited among the fruit-growers by the entomologists was in the least unjustified. It does not mean that the scale is controlled by parasites that have become habituated to it. Apparently it does not mean that our fruit-trees have developed qualities resistant to scale damage, although this has been suspected in regions which have harbored the scale for the greatest length of time. It does mean, however, that the entomologists and the orchardists have developed remedial treatment, applied especially during the dormant season, in the way of lime-sulphur and mineral oils, which destroys the overwintering scales and thus prevents serious damage during the following summer. The scale still exists in nearly all orchards, and there is always a reservoir of living material on untreated garden fruit-trees growing along the road sides or on waste lands. For some unknown reason, such trees, although stunted in their growth and producing very inferior and spotted fruit, continue to live for many years. Possibly, to a slight extent, they have developed resistant qualities.

But the United States grows as much and even more good fruit than it did thirty years ago, although at the cost of greater expenditure (Quaintance has estimated it at twenty millions of dollars each year). Winter washes have become an annual charge against the fruit-growers, and the control of the San José scale is simply another instance in which we are still obliged to spend great sums of money in fighting an injurious species while we are still trying to find some easier, cheaper and more natural means.

I should have stated earlier in this account of this insect, although perhaps it has been inferred, that intense investigation of its biology was begun at once and that it is one of the species that have been most studied by careful workers. When Comstock found it in the Santa Clara Valley of California he called it the pernicious scale. It is in some ways unfortunate that it has come to be known popularly as the San José scale. It was suspected for a time that James Lick brought it in from Chile on apple twigs, and at another time that he brought it from Japan. The question as to its origin was eventually settled by Marlatt who studied it in Japan and decided that Japan got it from the United States. He afterwards found it in China under such conditions as to show that its original home was north China. Further than that, he showed that in all probability James Lick imported it, possibly through the missionary, Dr. Nevius, on the flowering Chinese peach. Marlatt in his wonderfully interesting account of his search for the native home concludes that the insect should be known as the Chinese scale and that it came to this country on some ornamental stock from north China.

THE COTTON BOLL WEEVIL

Seemingly unimportant things that are later connected with great events are well worth recording. Back in 1843 a Swedish entomologist named and described in Europe a little weevil which had been collected by some one in Vera Cruz, Mexico. The entomologist was C. H. Boheman, and he called the weevil *Anthonomus grandis.* In 1871 a German entomologist named E. Suffrian recorded the same insect as occurring in Cuba. That is all that the world knew of this famous insect down to 1880. In that year a very interesting man named Dr. Edward Palmer, an Englishman by birth and a professional botanical collector, who had traveled greatly in Mexico for the U. S. Department of Agriculture and for Harvard University, found that a small, dark-colored weevil was doing great damage to cotton in the neighborhood of Monclova, Mexico. He sent specimens of this weevil to the Department of Agriculture in Washington with the statement that the insect had stopped the cultivation of cotton in that part of Mexico.

When Dr. Palmer's letter and specimens arrived in Washington (the letter was addressed to the then Secretary of Agriculture, J. M. Rusk), Professor Comstock was in California; E. A. Schwarz, the experienced beetle man, was then working with the U. S. Entomological Commission and not with the Department of Agriculture, and the writer, who knew very little about beetles and to whom the correspondence was referred since he was in charge of the entomological office, took the specimens to Mr. Henry Ulke, an artist, musician and famous collector of Coleoptera, who lived in Washington. The insect was new to Ulke, and he sent it to Dr. George H. Horn, of Philadelphia, the foremost American authority on beetles. The insect proved new to Dr. Horn also, and he in turn forwarded it to a well-known writer on the weevils, in Paris, Monsieur A. Sallé. Eventually the name came back, and we had at least the satisfaction of knowing the name of the Mexican pest.

No mention was made of this matter in any of the publications of the Department of Agriculture until 1885 when, Professor Riley having returned as chief of the entomological service of this department, the mere fact was mentioned in his report for that year.

Again some years elapsed, and then the species was brought very forcibly to the attention of the department. On October 3, 1894, Mr. C. H. DeRyee, of Corpus Christi, Texas, sent the following letter to the Department of Agriculture in Washington:

> The "Top" crop of cotton of this section has been very much damaged and in some cases almost entirely destroyed by a peculiar weevil or bug which by some means destroys the squares and small bolls. Our farmers can combat the cotton worm but are at a loss to know what to do to overcome this pest. They claim the ordinary methods of poisoning for cotton worm have no effect on these bugs. They probably deposit their eggs in the square and their larvae enter the boll as soon as sufficiently formed and are there out of reach of the poison.
>
> Will you kindly, for the benefit of our farmers, let me know what this pest is and send me any literature that may be available with information which will enlighten and benefit our farming people.
>
> I send you by mail to-day a lot of these bugs put up in a small vial. Have put some coarsely ground flax seed in with them which may keep them alive till you receive them.

Mr. DeRyee was a member of the firm of DeRyee and Bingham, dealers in drugs and medicines. The exact locality from which these specimens came was not given, but it was obviously not very far from Corpus Christi. The original sendings did not reach Washington, and an additional sending was requested. On October 26, 1894, more were received and were identified as *Anthonomus grandis* by Dr. Schwarz, who had re-

sumed his work in the Department of Agriculture. The situation appeared to be so serious that C. H. Tyler Townsend was sent from the department, and from November 15 to December 15 traveled in south Texas and adjacent Mexican territory, and submitted an alarming report.

Between the time when Dr. Palmer found the insect at Monclova and the receipt of Mr. DeRyee's letter just quoted, it had begun to do damage at points farther east, and from Matamoras had crossed the Rio Grande at Brownsville. It must have been in the Brownsville region before 1894, but north of this point there was a large area in which there was no cotton. Evidently, however, cotton had been carried for ginning north to Alice, and thus the insect became established in the good cotton region about Alice, San Diego and Corpus Christi. Mr. Townsend reported that the damage to the crop during 1894 in this latter region amounted to from 75 to 90 per cent. The remedies that he suggested included burning the fields, flooding where this was possible, rotation of crops, picking and burning the bolls and turning cattle, hogs, etc., into the cotton fields. He especially recommended the abandoning of cotton throughout a wide strip of country along the Texas border. He showed that a fifty-mile non-cotton zone would protect the United States, and gave it as his opinion that crops more valuable by far than cotton could be raised in the territory.

The following year the insect spread further. Mr. Townsend was in the field and was joined by E. A. Schwarz and later by the writer; by the close of the year the weevil had been found as far north as San Antonio and as far east as Wharton. Texas had become seriously alarmed. The then governor of the state (Charles A. Culberson, later for many years U. S. senator) visited Washington the following winter. He was an old friend of Dr. C. W. Dabney, at that time Assistant Secretary of Agriculture. The writer was called into consultation, and the governor was strongly urged to forward legislation by the State of Texas establishing an anti-pest law and creating a non-cotton zone for the protection of the rest of the state and the rest of the cotton belt—a law, in fact, comparable in many respects to the state pest law of California which was the first state law of this kind to be adopted. The plan met with the governor's approval, the bill was drafted and presented to the Texas state legislature, but it failed to pass, and it seems safe to say that the responsibility for the enormous loss which followed lies at the door of that particular legislature.

The spread of the insect continued.[1] A state convention was held at Victoria, Texas, and was attended by many planters, bankers and merchants. The legislature of the state passed a bill providing for the appointment of a state entomologist with a limited appropriation for an investigation.

The U. S. Department of Agriculture, realizing that the state wished to do this work, stopped its own investigations and referred all correspondence to the new state entomologist of Texas.

[1] In April, 1896, Dr. Marlatt, in the course of a general trip of inspection to the Southwest, including California, spent a week studying the boll weevil situation in southern Texas, and in cooperation with Judge Borden conducted some tests with arsenical sprays. These tests demonstrated clearly that the early-appearing weevils fed readily on volunteer cotton, piercing the leaves with minute holes, and could be easily killed by an arsenical application. The possibility of thus destroying overwintered weevils on volunteer cotton prior to the appearance of the newly planted crop had special significance on account of the belief that the weevils never feed on the leaves and that therefore arsenical applications to the foliage would be valueless. These tests were the basis for the recommendation of poisoning volunteer cotton, the weevil at that time being limited very largely to a region of such volunteer growth.

The spread, however, continued, and as it became certain that other states were threatened the federal government once more took up the investigation in the spring of 1901. The late W. D. Hunter was appointed to head the work, and continued in charge until his lamented death in October, 1925.

Hunter and his associates, notably Dr. W. E. Hinds (now state entomologist of Louisiana) and later Dr. W. D. Pierce, built up a strong organization, and very early decided, after a very large-scale field demonstration, that a change of agricultural methods was necessary. They demonstrated that, with the use of an early-maturing variety of cotton and a forcing of the crop, bringing about an early harvest, and the destruction of all cotton standing in the field by the end of October, damage by the weevil could be reduced to the minimum and its spread greatly delayed. Little or no attention, however, was paid to the recommendation. In the main, cotton continued to be planted and harvested in the same old way, and the spread of the insect continued. It crossed into Louisiana in 1903, into Mississippi in 1907 and so on year after year until, in thirty-one years after the crossing of the Rio Grande, it had invaded practically all the more than six hundred thousand square miles included in the so-called cotton belt.

No one who has never lived in the South can appreciate what this meant. At the time of the weevil's advent, so large a measure of the prosperity of the South depended upon this one crop that its loss practically affected every industry and every individual. As it spread year after year, partial paralysis followed it at first. Mortgages on old plantations were foreclosed; Negro labor fled before the weevil's advance; wealthy families were reduced to comparative poverty; banks failed; planters and speculators committed suicide.

All these things happened, and happened very many times, but the spread of the weevil seemed as inexorable as fate. Louisiana made a desperate stand against its entrance from Texas, but did not cause it more than a temporary delay; and after the Mississippi bottom lands were invaded it became apparent to all thinking and far-sighted men that the situation of the cotton belt was little short of desperate. But the mass of the planters paid little heed to the warnings and advice of the experts. Wise prophets were scouted as alarmists, and very many took the stand that measures should be taken when the weevil should come and not before, apparently feeling that something indefinite would happen to retard or stop the spread and so save them. It is true that a delegation of prominent men from the Carolinas and from Georgia visited the infested regions and the government laboratory in Louisiana at one time and grasped the seriousness of the situation and foresaw the future disastrous results of the do-nothing policy. These men issued advice and warning to the planters of their states. But their prophetic wisdom met with no adequate response, and impoverishment, failure and suicide marched steadily along with the weevil's progress.

It is true also that, under the urge of the federal government and with the support of Congressional appropriations, a great campaign was started "to meet the emergency caused by the advent of the boll weevil," and that strenuous efforts were made to start new agricultural industries, to vary the crops, to draw the South from its absolute dependence on a single culture. This movement was the beginning of a wave which has run over the South and laid the groundwork for the rapidly growing activities now to be seen all through that portion of the country.

Nevertheless, history repeated itself again and again. After a few years of weevil, that is to say, a few years of failure and despair, an invaded state or

section of a state began to recover hope, to vary its crops and to continue to grow cotton, at a greater cost it is true, but with the spirit of enterprise and fight that carried it once more into a condition of comparative prosperity. Poor cotton lands have been abandoned; better ones have been more intelligently worked, and good crops have been grown in spite of the weevil.

All through this era, and in spite of the discouragement due to apparent lack of appreciation on the part of the public, the entomologists have worked manfully. The original headquarters of the investigation at Victoria, Texas, were early removed to Dallas and later to Tallulah, Louisiana. As the northeastern part of the cotton belt was invaded a substation was established at Florence, South Carolina, where, in cooperation with the state, careful investigations were carried on to decide the variations in the life history of the extremely adaptable weevil which might have been brought about by its invasion of new and somewhat different territory.

Able minds of trained men were constantly searching for new light, and every suggestion that was made, not only by men familiar with the cotton crop but by ingenious individuals all over the country and in fact in many parts of the world, was tested by the experts. And these experts included not only the men in the federal service but also the official entomologists of the different states. As to these last men, it may be stated that, although at the beginning of the cotton boll weevil investigation there was hardly a single trained economic entomologist in the South and in fact no educational institution that trained such men, the lack was soon noted, and the Southern colleges and universities took up entomology and began to turn out strong and well-trained young men.

At the time of present writing, in spite of the enormous loss which has been caused by the weevil, conditions in the South are immeasurably better than they were twenty-five years ago. It is true that the abolition of the menace of yellow fever and the practical abolition of the hookworm have been tremendous boons, but the boll weevil experience has probably been a blessing in disguise—in a very terrible disguise, but nevertheless a blessing. Appreciation of the fact is slowly coming. In fact, in at least one locality it was realized a number of years ago, when a statue was erected to the boll weevil by the citizens of Enterprise, Alabama, with the legend, "In profound appreciation of the boll weevil and what it has done as the herald of prosperity."

The very competent cotton planter and economist, Mr. Alfred Stone, of Mississippi, in an address before the U. S. Chamber of Commerce in Cleveland, Ohio, in 1924, advanced the idea that "the boll weevil is not the dominantly controlling factor in cotton production which it is thought and claimed to be by the average man who considers or discusses the subject." He went on to say that if this were true

> it would follow as a logical sequence that the final control of the weevil would mean such an oversupply of American cotton as would glut the markets of the world. If this were true then the control of the weevil would be a calamitous thing for the cotton grower, instead of a benefit, for his product would share the inevitable economic fate of the extreme overproduction of any commodity.

As early as 1924, Dr. Clarence Poe, the editor of the *Progressive Farmer,* summarized nine clearly indicated and logical results of the boll weevil investigation in addition to the obvious result that the one-crop system was being done away with and that diversification was being promoted. The nine results discussed by Dr. Poe were as follows: (1) The boll weevil is speeding up the processes of agricultural evolution in the South. (2) The boll weevil discourages absentee landlordism, which has been one of the great curses of the South.

(3) The ancient crop-mortgage, "time-prices" system, which has so long cursed the South, has also been hard hit by the coming of the boll weevil. (4) Agriculture will become more nearly boss of itself and not the tool of the mercantile interests. (5) The boll weevil sharply penalizes the traditional indifference to soil fertility which has also been one of the curses of the South. (6) The boll weevil necessitates higher grade tenants and renters and disperses those who do not come up to the new standards. (7) We must now have more intelligent labor, even to make cotton profitable, and this opens the way for other lines of farming progress heretofore neglected. (8) The boll weevil penalizes agricultural indifference and insures agricultural alertness. (9) Last but not least, the coming of the boll weevil promises to give us on Southern farms a greater proportion of men who really love farming. . . . The weevil has greatly intensified the struggle for the "survival of the fittest" and has caused thousands of the unfit to go into other industries and other sections. . . . From now on, cotton growing demands alert intelligence. The boll weevil has speeded up both the passing of the clodhopper and the coming of the up-to-date farmer.

In the great boll weevil investigation two names stand out most prominently among those of many who from time to time have been connected with it, namely, W. D. Hunter and B. R. Coad.

W. D. Hunter, of Nebraska, selected for the work in the spring of 1901 on account of the ability he had shown in another investigation, stayed in the cotton states, mainly in Texas, for the rest of his life. Centering around the boll weevil, his work gradually came to cover the whole subject of insects injurious to Southern field crops, and later of insects affecting domestic animals and the health of man. He was respected and loved by many of the most prominent people of the South, and no man was ever more sincerely mourned. He combined scientific methods and scientific insight with a broad knowledge of practical affairs to an extent seldom found in an individual.

B. R. Coad came to the laboratory at Victoria, Texas, from the University of Illinois in 1911. In 1915 he was placed in charge of the boll weevil laboratory at Tallulah, Louisiana, and Dr. Hunter gradually turned over to him the entire management of the boll weevil work. Coad developed the process of cotton dusting with calcium arsenate to such a perfection that it became the standard protection of cotton against the weevil, and later brought about the use of aeroplanes for the distribution of the poison dust over large areas. Many people think that it has been very largely through his labors that cotton can be grown profitably in the presence of the weevil. He is now in charge of the work on cotton insects for the U. S. Bureau of Entomology.[2]

[2] While I have omitted mention of state officials, a number of whom did excellent work in the course of the investigation of this pest, the name of Wilmon Newell stands out for a very special reason. Mr. Newell went south in 1902, and was stationed for a time in Texas. In 1903 and most of 1904 he was state entomologist of Georgia, and in the latter part of the latter year he was made entomologist of the Louisiana Experiment Station and secretary and entomologist of the Louisiana Crop Pest Commission. These posts he held until 1910, when he returned to Texas; eventually, in 1915, he became plant commissioner for the State Plant Board of Florida. In 1921 he was made dean of the College of Agriculture of the University of Florida, director of the Florida Experiment Station and director of the agricultural extension division of the University of Florida. His name stands out among the workers on the cotton boll weevil for the reason that in 1907, in Louisiana, he first tried powdered lead arsenate against the boll weevil. Large field tests followed in 1908 and 1909, and the results showed a decided increase in the yield on the poisoned plots. This was the first use of an arsenate in powder form against the weevil, and undoubtedly led naturally and

But the work, largely biological, of Hinds and Pierce and of many other assistants must not be forgotten. Possibly no other insect is better known to-day than is *Anthonomus grandis*.

I first visited the field in 1896, joining Townsend and Schwarz. Again I joined Hunter in the summer of 1901, and for many years thereafter went to the South each year to see the conditions and the work. So vivid were the impressions I gained, so novel were the experiences, so many and so delightful were the new Southern friends and so sad was the plight of many of them, that for many years the South, the Southern people and the boll weevil were uppermost in my mind. The bravery of the people, the wonderful way they accepted a burden that would in any other region have driven thousands to despair, was a revelation to me. They actually joked about this small but terrible enemy; cheap cigars were called "boll weevils"; signboards said, "Forget the boll weevil and come to [such and such a] show"; the boll weevil became a daily and even an hourly word; the man in the street was heard in a fight to call his opponent a blank blank boll weevil—evidently nothing worse, in his opinion, could be said. A politician in the heat of political argument was quite apt to call his opponent a boll weevil. A prominent official of one state was called "the greatest boll weevil the State of Mississippi ever produced."

Dr. Hunter once told me that the boll weevil had figured in a number of romantic tales, some of them dealing with the villainous introduction of the insect for the purpose of wreaking vengeance on a community. Of course the insect figured often in the newspaper cartoons. One of the best of them appeared in the *News* of Greenville, South Carolina, in 1911. It showed a gigantic boll weevil standing partly in Georgia and partly in Alabama, its shadow beginning to strike South Carolina. In its hand it held a black flag with skull and cross-bones, and the legend read, "In the shadow of the pest."

And it got into poetry and even into the only folk-song we have in the United States—that of the Negro. One of the longest and best of these is a narrative work song recorded by Professor Gates Thomas, of the Southwestern Texas State Teachers College at San Marcos, in the *Publications* of the Texas Folk-Lore Society.[3] The two stanzas at the end of this song are as follows:

The boll-weevil sez to the farmer, "What make yo' neck so red?"
"Tryin' to beat you devils; it's a wonder I ain't dead;
For you're takin' my home, Babe, just a-takin' my home!"

"Well ef you want to kill us, I'll sho-God tell yo' how:
Just bundle up yo' cotton sack and th'ow away yo' plow;
Then hunt yo' a home, Babe, then hunt yo' a home."

Note that the boll weevil itself makes practically the same recommendation for its own extermination that Townsend made in his original report in the winter of 1894–95 and that was urged upon the governor of Texas by Assistant Secretary Dabney and the writer.

INSECTS AND DISEASE OF MAN AND ANIMALS

The last of the four striking discoveries of the last decade of the last century which have been so instrumental in the promotion of work in applied entomology was the demonstration in 1898 by Ross in India that certain mosquitoes carry malaria and that only through their punctures do people get malaria. This was one of the most important, far-reaching and revolutionary discoveries ever made in the etiology of disease.

Although Manson had previously proved the transmission of filariasis by

directly to the development of calcium arsenate by Coad and the subsequent use of that material on such a broad scale throughout the cotton belt.

[3] No. 5 (1926), pages 173 to 175.

mosquitoes and although Smith and Kilborn had demonstrated the carriage of the Texas fever of cattle by ticks, the insect transmission of disease was brought before the people with immense force by Ross's work. Malaria was practically a world-wide malady; millions of people were subject to it, and it is therefore no wonder that the attention of investigators everywhere was drawn to this new field and that by their work the field was broadened out to an extraordinary degree. Almost immediately Ross's results were confirmed in Italy, and anti-malaria work from the mosquito standpoint was begun in many parts of the world.

In a very short time the work of Reed, Carroll, Lazear and Agramonte demonstrated that without a doubt yellow fever is also mosquito-borne and is transferred only by a certain species of mosquito. Medical entomology became at once an important field of investigation. Discoveries followed one another with rapidity. New schools of tropical medicine were founded, and teaching in these subjects was begun in the medical colleges. In the thirty odd years that have elapsed since Ross's discovery thousands of papers have been published giving the results of research work all over the world, and large and comprehensive books have been published on medical entomology. In fact, the world's output of scientific papers relating to this kind of scientific work has become so great that their titles alone crowd the pages of the bibliographical journals, while at least one journal of this kind has been established solely for the review of this mass of special scientific literature.

So rapidly did discoveries mount in number that as early as 1921 W. D. Pierce, in the large book edited by him and entitled "Sanitary Entomology," devoted twenty-seven pages (in fine print) to the mère listing of the maladies of man and domestic animals that are spread by insects, of their insect transmitters and of the secondary hosts of these insects where such are involved. The four years and more of the world war, while interrupting scientific investigation to a certain extent, incited work on some of the problems of this nature, and many important facts were discovered and many important results were gained.

It is perfectly true that most of the main discoveries in medical entomology have been made by medical men, but all future work demands the intimate cooperation of pathologists and entomologists. The control of an insect-borne disease, whether of man or of domestic animals, means primarily the control of the carrier; and who is so competent to investigate the possibilities in that direction as the man trained in economic entomology? Down to the present time perhaps the entomologists have realized this more than the medical men have. It has happened too often that medical investigators have underestimated the need of colleagues trained in entomology. They have underestimated the difficulties of entomological study. What has appeared simple to them has been shown often to be extremely complex. But the old ideas are passing away, and the vital need of cooperation in this as in so many other directions is apparent.

The great French parasitologist, Raphaël Blanchard, once said (translated):

> The rapid movement which leads medicine into the current of parasitology can not be stopped. In reality these two branches of general biology seem more or less distinct, but, as two rivers whose waters meet and flow side by side for a certain distance soon come together, so parasitology may include almost the entire domain of medicine.

This may be the extreme view of an overenthusiastic parasitologist, but it can not fail to emphasize the importance of the study of the insect carriers of parasitic diseases.

SOME ASPECTS OF OCEANOGRAPHY

By Dr. HARALD U. SVERDRUP[1]

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To the student the ocean waters represent a wide field of research ranging from an investigation of the physical properties of the water to an examination of the unlimited number of organisms living in the sea and the conditions for their growth and development. Many branches of oceanography can be treated independently. Thus it is possible to study the currents and their relation to the winds or the distribution of the density without regard to the chemical composition of the water or to examine the different forms of organisms without considering the character of their environment. However, in many cases a combination of the knowledge which has been derived from the various isolated investigations is indispensable, for example, when dealing with the conditions for the development of organisms. In this survey the treatment of the subject will not be general but will be confined to one factor which is of importance, namely, the transfer from one water layer to another of substances which are essential to the development of organisms.

Numerous investigations of the composition of the sea water have shown that the composition is constant as far as the major constituents are concerned. The salts which occur in considerable quantities are always present in the same ratios, although the total content of salt varies from one region to another. Besides these major components, which together determine the salinity of the water, there are always present minute quantities of other compounds, which are of no importance to the total salinity of the water but of the greatest importance to the organisms in the water, for example, the nitrates, phosphates and silicates in the sea. These substances are indispensable to the life of organisms, and especially the nitrates and phosphates have been called the fertilizers of the sea. These substances occur, as already mentioned, in very small quantities. In the Pacific at a depth of 1,000 meters the total weight of salt in one kilogram of water is equal to 34.5 grams, according to the determinations which were made on board the *Carnegie,* while the total weight of phosphor pentoxide is only about 0.2 milligram and the corresponding figures for the surface waters are 35 grams and around 0.01 milligram.

Chemists have only recently succeeded in determining these imperceptible quantities accurately, and our knowledge of the distribution of the fertilizers of the sea is therefore still scanty. However, the observations from the coastal waters of Europe, the South Atlantic and recently the observations from the Pacific which were made by the *Carnegie* have already shown that the content of phosphates and nitrates varies much from one place to another and that the variation with depth is extremely large, the content being small in the surface layers but great in the deep water, as illustrated by the figures from the Pacific which I mentioned. Considering these great variations it is evident that the transfer of these substances from one water layer to another is of eminent importance. An intensive development of organisms takes place only in the upper layers of the sea, because the presence of light is an essential condition for the de-

[1] Based on an address delivered on April 8 at the Carnegie Institution of Washington.

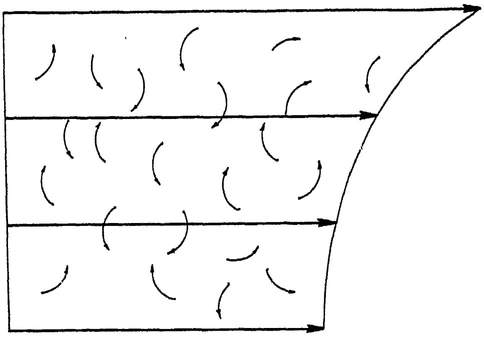

FIG. 1. SCHEMATIC REPRESENTATION OF EXCHANGE OF MOLECULES BETWEEN DIFFERENT LAYERS. THICK ARROWS REPRESENT HORIZONTAL FLOW.

velopment of the plant life which again forms the basis for the animal life, and a sufficient amount of light does not penetrate to great depths. The small amounts of phosphates, nitrates and silicates in the upper layer must be attributed to the circumstance that these substances are being used there for the building up of organisms, but since this building up goes on constantly it must also be assumed that a regular transfer of fertilizers from the deeper layers takes place. The same substances, on the other hand, are brought back again to the deep water when the dead organisms are sinking. The organic substances are then decomposed and the components dissolved in the water.

In addition to the nitrates, phosphates and silicates, mention must be made of the important part which is played by oxygen and carbonic acid. Three factors tend to increase the amount of oxygen in the sea, namely, the absorption of oxygen from the atmosphere, production of oxygen during the assimilation processes of the plant organisms and transfer of oxygen from another layer. During the second process carbonic acid is assimilated and transformed to organic substances. The oxygen content within a given body of water decreases under the action of three factors, namely, respiration of the animals which produces carbonic acid, the decomposition of organic matter which in the last stage also increases the amount of carbonic acid and finally the transfer to other bodies of water. When studying the oxygen and carbonic-acid content of the sea water it is, therefore, also necessary to consider the transfer of these dissolved gases. This means that we have to deal with the same problem as in case of the distribution of nitrates and phosphates. We encounter the same problem when studying the conduction of heat in the sea or when discussing the currents in the sea, especially the currents which are produced by wind or the currents in the vicinity of the bottom. In this last case we are concerned with the transfer of kinetic energy from one layer to another, and this type of transfer will be dealt with first in order to apply the results to other problems of conduction.

The study of the transfer of kinetic energy in the sea has been going on for a number of years and has brought out the surprising result that the sea water apparently has a viscosity which is something around 10,000 times greater than the viscosity of water as determined in the laboratory. In order to understand

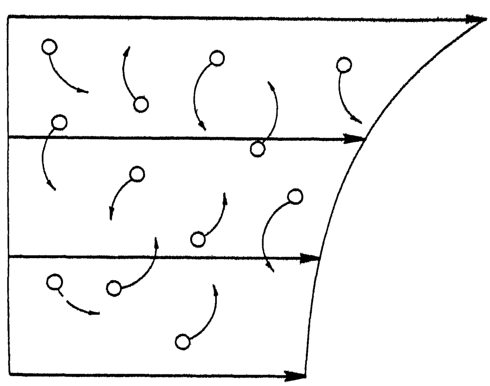

FIG. 2. SCHEMATIC REPRESENTATION OF EXCHANGE OF PARTICLES BETWEEN DIFFERENT LAYERS ON ACCOUNT OF EDDY MOTION. THICK ARROWS REPRESENT AVERAGE HORIZONTAL FLOW.

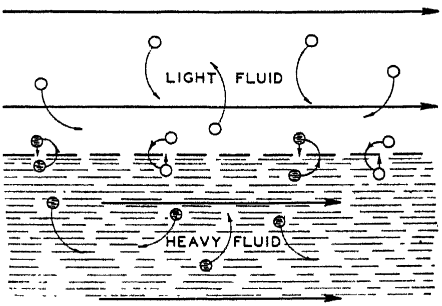

FIG. 3. SCHEMATIC REPRESENTATION OF EXCHANGE OF PARTICLES BETWEEN TWO LAYERS OF DIFFERENT DENSITY. THICK ARROWS REPRESENT AVERAGE HORIZONTAL FLOW.

this result it is necessary to compare the character of the ordinary viscosity of the water with the character of the apparent viscosity of the sea water.

The ordinary viscosity of a fluid is ascribed to the irregular movements of the molecules of the fluid. An attempt to represent these irregular movements graphically is made in Fig. 1, supposing that each water particle is moving horizontally but that the horizontal velocity changes with depth as indicated by the length of the arrows. Furthermore, the irregular movements of the molecules are indicated by the thin and irregular arrows. Let us consider the central part of the fluid. The molecules which move away from this part will be replaced partly by molecules coming from above and partly by molecules coming from below. The mean horizontal velocity of these molecules is greater than the mean horizontal velocity of the molecules which left the layer, and consequently the horizontal velocity within the layer increases, which in the present case means that the differences in velocity are smoothed in the course of time. However, the molecules represent only minute particles and the smoothing will therefore take a long time, which means that the viscosity of the fluid is small. In case of water the viscosity can be expressed by a coefficient which in the centimeter-gram-second system has a numerical value of 0.017 at a temperature of 0° C. We have here assumed that the water particles move horizontally while only the molecules are moving irregularly. This assumption is valid

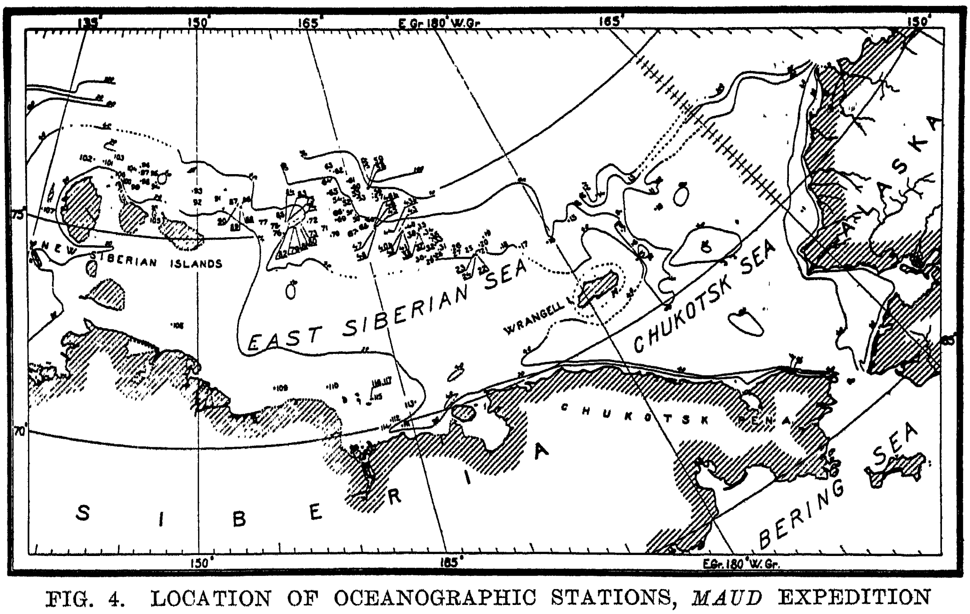

FIG. 4. LOCATION OF OCEANOGRAPHIC STATIONS, *MAUD* EXPEDITION

FIG. 5. THE *MAUD*

only as long as we are dealing with small velocities within a very small body of water. As soon as we have a large body of water the character of the motion changes entirely. The average velocity within a layer may still be horizontal, but every single little mass of water now moves irregularly and the motion is characterized by a number of irregular eddies as indicated in Fig. 2. In the former case molecules were exchanged between the neighboring layer; now small water masses are exchanged. This naturally leads to a much more rapid smoothing of existing differences in the average horizontal velocities because a small body of water transfers much more energy from one layer to another than a molecule. As a consequence the fluid apparently has a very great viscosity, which, using the same units as above, can be expressed by a number which on the average is about 200. This viscosity which actually has to be taken into account when dealing with the currents in the sea has been called the eddy viscosity in contrast to the ordinary molecular viscosity. It is evident that the eddy motion is of importance not only to the transfer of kinetic energy but also to the transfer of heat and dissolved substances because the water particles which are exchanged between different layers carry their characteristic properties with them. We therefore talk not only about eddy viscosity but also about eddy conductivity and eddy diffusion which are many thousands times greater than the corresponding conductivity or diffusion in the absence of eddies.

The coefficient which expresses the transfer is not constant, because it depends entirely upon the development of the irregular eddies. The development of the eddies depends again upon several factors of which should be mentioned especially the stratification of the water. Let us suppose that we have a layer of light water above a layer of heavy water and that these two layers are separated from each other by a thin layer of transition. If a particle moves upwards from the heavy layer it becomes surrounded by much lighter water and drops back again to the layer from which it came on account of the action of gravity. A particle which moves downwards from the lighter layer is, on the other hand, driven back again to that layer as illustrated in Fig. 3. As a consequence only very small eddies develop at the boundary of the two fluids, and the transfer of kinetic energy or dissolved substances from one layer to another is small, which means that the eddy viscosity and the eddy conductivity are small at a boundary surface.

We can thus easily arrive at qualitative conclusions regarding the variations of the eddy viscosity, but it is difficult to obtain observations which allow an examination of the actual conditions in the sea, because such an examination has to be based on current observations which can be obtained only from an anchored vessel or under exceptional conditions, for example, in the Arctic from a vessel which is enclosed by ice. The *Maud* drifted with the ice north of the Siberian coast for two years and we had then a unique opportunity of studying the currents and the general oceanographic conditions of the waters. These studies have led to several results regarding the eddy viscosity and the conduction of heat, and we shall, therefore, enter more fully upon some of the observations.

The major part of the oceanographic work of the *Maud* was carried out during the years 1922–24 when the vessel was drifting with the ice on the North Siberian Shelf. The distribution of our stations is seen from Fig. 4, in which

FIG. 6. SOUNDING HOLE IN THE ICE

curves of equal depth are entered. These curves are drawn for intervals of depth of twenty meters, or about ten fathoms, and they show the shallowness of the coastal waters north of Siberia extending a great distance from the coast. The one hundred meter or fifty-fathom curve can be followed at a distance from the coast of approximately four hundred nautical miles on the whole stretch from Alaska to the region north of the New Siberian Islands. However, if we examine the details we find a marked difference in the character of the bottom within the different regions of the shelf.

To the east of Wrangell Island, the depth varies rather irregularly between sixty and less than twenty meters, but to the west of Wrangell Island the depth increases with remarkable regularity, the forty-meter or twenty-fathom curve being about two hundred nautical miles from the coast. The difference in topography of the bottom in the two areas is undoubtedly to a great extent responsible for the difference in the general hydrographic features and for the different character of the currents. However, we shall not deal with these differences, but shall discuss only the conditions in the East Siberian Sea. These are, on account of the remarkable smoothness of the bottom, very outstanding and very well suited for studying the character of the eddy viscosity of the water under different conditions.

Before discussing details it is desirable to form an idea of the conditions under which the oceanographic observations were taken. The vessel, the *Maud,* as already mentioned, was enclosed by the ice and drifted with the ice approximately along the route which is indicated on the map by the distribution of the stations. The ice sur-

rounding the vessel remained unbroken for months and we had, therefore, to keep a hole open in order to carry out soundings and take water samples. The ice which froze during the night over this hole had to be removed every morning and was thrown aside at the hole, which at the end of the winter had taken the appearance of a crater.

Through this hole we took our soundings and lowered our water-bottles, which were provided with reversing thermometers for determining the temperature of the water. The water-bottles had to be brought into the laboratory as soon as possible after they had been hauled up in order to prevent freezing of the contents. In the laboratory they were emptied and the thermometers were read. We usually took samples to determine the chlorine content, the density, the oxygen content and the hydrogen-ion concentration. The methods of determining nitrates, phosphates and silicates had not been developed when the *Maud* left civilization in 1922, and the investigation of these important factors was, therefore, not on our program. All determinations were carried out in the small laboratory. It is to be noted that the content of salt of the water, the salinity, can be found both from the chlorine content and the specific gravity, supposing the composition of the water to be the same as in the Atlantic Ocean and the European waters. The water off the Siberian coast has a lower salinity than the Atlantic water on account of admixture of fresh water from the great Siberian rivers, and the composition might be different because of this admixture. However, we found only a very small discrepancy between the values which were derived from the two independent determinations, for which reason we conclude that the composition of the water off the Siberian coast is very nearly like the composition of the Atlantic water. The data from the *Carnegie* show that the same is true for the composition of the waters of the Pacific. These observations thus support the conception that the composition of sea water is nearly the same all over the world. This conception is now shared by many oceanographers, but we are much in need of observations from many more regions before we can rely upon the fact that it is correct.

The subsurface temperatures were determined on board the *Maud* by means of thermometers which were graduated to one tenth of a degree and were read to one hundredth of a degree. One might think that it is impossible to determine the temperature at a considerable depth with an accuracy of one hundredth part of one degree, but that this is possible is shown by the excellent agreement of all the thermometers. The difference between thermometers which were used in pairs was zero in the greatest number of cases, and only in few instances exceeded two one hundredths. We could also check the absolute values. The water directly under the ice remained at freezing-point during the greater part of the winter, and knowing the salinity of the water we could compute this freezing temperature, which on the average agreed with the observed temperature within less than one hundredth part of one degree.

The differences between thermometers which were used in pairs on board the *Carnegie* are scattered over a wider interval, and differences amounting to two or three one-hundredths are more frequent. The thermometers of the *Carnegie* were lost, for which reason it has been impossible to reexamine them after their use and take into account the small changes in the corrections which have taken place. Under these circumstances it is remarkable that the thermometers agree so well, and the results attest well the workmanship of the makers of the in-

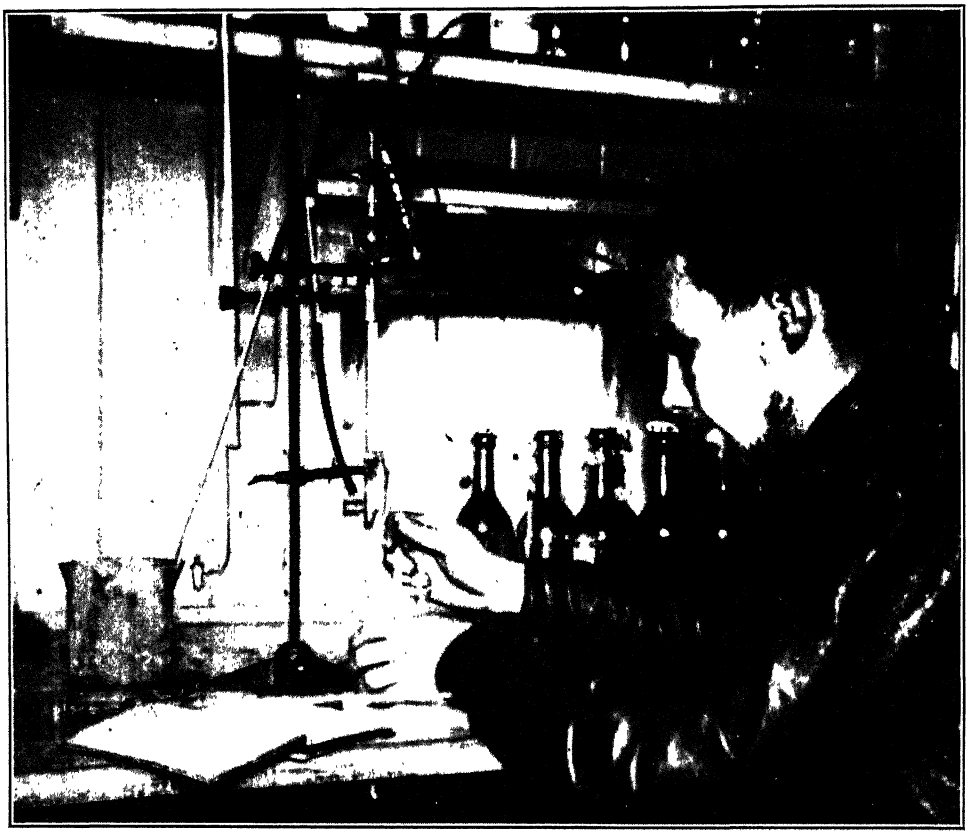

FIG. 7. LABORATORY ON THE *MAUD*

struments and the conscientiousness of the observers on board the *Carnegie*.

Even though one may admit that so high a degree of accuracy can be obtained one may feel that it is quite unnecessary to attempt to reach this accuracy in the temperature determinations, assuming that no conclusions can be drawn from differences in temperature amounting to only a few hundredths of a degree. However, our hopes that such use can be made and our efforts to increase the accuracy of the temperature observations are justified.

A knowledge of the subsurface currents in the sea is as a rule obtained on the basis of the observed temperatures and salinities. When computing the currents, it must, however, be assumed that the time interval between the oceanographic stations is so short that the observations at the different stations can be regarded as simultaneous or that conditions are stationary. Neither of these assumptions is valid in our case. In order to get information about the current we had, therefore, to carry out direct measurements. We could determine the drift by means of astronomical observations, and in addition we could measure the movement of the water relative to the movement of the ice by means of current-meters. We availed ourselves in the beginning of the Ekman current-meter which is used extensively in temperate climates, but soon found that this instrument was not suited very well for use in the Arctic. As soon as it was

taken from the water and came in contact with the cold air it became coated with ice, which choked all movable parts, and it had to be taken indoors and heated and cleaned before it could be used again. We evidently needed an instrument which could be left in any desired depth and which recorded the currents by means of some electrical device. Mr. Dahl and the writer succeeded in constructing an instrument of this type which functioned satisfactorily during fourteen months and gave us much valuable information about the currents under the ice.

The present discussion of the results will deal only with the conditions of the East Siberian Sea where outstanding features were met with. On the northern part of the shelf, where the *Maud* drifted, the water was typically stratified. Near the surface we found a layer with a constant temperature and constant salinity extending down to a depth of about forty meters. Under this homogeneous layer we found a thin layer of heavy bottom-water, characterized by high salinity, as illustrated by an example in Fig. 8.

The two layers are separated by a very thin layer of transition. On April 3, 1923, the salinity increased for instance from 29.78 parts per thousand at 37.5 meters to 32.02 parts per thousand at 40 meters. A layer of transition which is so sharply developed acts as a surface of discontinuity, and the two layers, the light surface-layer and the heavy bottom-layer, move and behave as if they were separated by a solid wall. No energy and no heat or any of the substances which are dissolved in the water are exchanged between the two layers. Let us first consider the currents. We made extensive observations of the tidal currents and their variations with depth, and the results from one station at the end of April, 1923, are represented in Fig. 9, showing the tidal currents in a vertical section. A curve, showing the variation of density with depth, has also been entered in this figure. The tidal currents were actually rotating, and the figure, therefore, represents only the components of the current in the vertical plane which has been selected. The greatest distances from a vertical through the center of the figure to the curves represent the maximum tidal current in the different depths. At that time of the year the ice took no part in the tidal motion because it was so tightly packed that it could not be carried back and forth by the tidal currents. The tidal currents, therefore, run between two solid surfaces, the ice and the bottom, and were zero at the bottom and directly under the ice. Proceeding upwards from the bottom the tidal currents increase with the distance from the bottom and reach a maximum at the upper part of the bottom-water, decreasing to imperceptible values within the layer of transition and remaining insignificant in the upper layer. The boundary layer could be replaced by a solid surface without altering the character of the observed currents materially, which means that practically no kinetic energy is transferred through the boundary layer separating the upper layer from the bottom-water. The variations of the tidal currents with depth allow a rough computation of the eddy viscosity which is an expression for the transfer of kinetic energy. In centimeter-gram-second units the eddy viscosity has a value of about 1,000 in the upper layer, indicating that a thorough mixing of the water goes on. Within the layer of transition the value is too small to be determined, but in the bottom-layer it again increases to about 40.

From the character of the observed tidal currents we conclude that no perceptible transfer of heat, dissolved substances or gases takes place through the boundary layer. This conclusion is con-

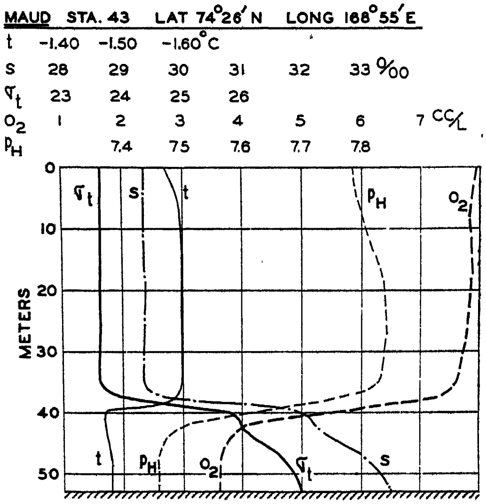

FIG. 8. VERTICAL DISTRIBUTION OF TEMPERATURE t, SALINITY S, DENSITY σ_t, OXYGEN CONTENT O_2 AND HYDROGEN-ION CONCENTRATION pH AT THE *Maud* STATION No. 43.

firmed by an inspection of the vertical distribution of the oxygen content and the hydrogen-ion concentration. The content of oxygen is constant within the upper layer but decreases suddenly at the boundary layer. The bottom-water contains very small quantities of oxygen, and this applies especially to the water of salinity 32 to 33 pro mille or parts per thousand which forms the characteristic bottom-water on the greater part of the shelf. The course of the curves representing the distribution of the hydrogen-ion concentration is very similar to the course of the oxygen curves. A close relation exists between the hydrogen-ion concentration and the content of carbonic acid, and our observations show that the bottom-water contains a great amount of carbonic acid. The small content of oxygen and the large content of carbonic acid in the bottom-water must result from the respiration of organisms living at the bottom or from the decomposition of organic substances falling to the bottom. Both these processes decrease the amount of oxygen and increase the amount of carbonic acid.

The conditions for development of organisms in this bottom-water are not good because the supply of oxygen from above is shut off by the boundary layer which is found at a distance of only five to ten meters from the bottom. This boundary layer isolates the bottom-water so well that within the bottom-water a rise of temperature seems to be present which must be due to the very small amount of heat which is conducted through the bottom from the interior of the earth. Such a rise would not be perceptible in absence of the boundary layer because the heat which is transported through the bottom would then be a negligible quantity as compared with the heat which would be transported to the bottom-water from above.

The bottom-water on the central part of the shelf has a salinity of 32 to 33 pro mille or parts per thousand. We have studied the movement of this bottom-water by means of continuous registrations of the currents. Our observations seem to indicate that the bottom-water

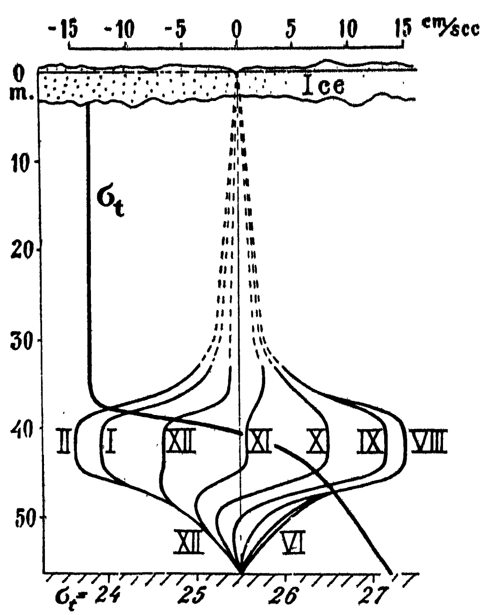

FIG. 9. VERTICAL SECTION TO SHOW TIDAL CURRENTS.

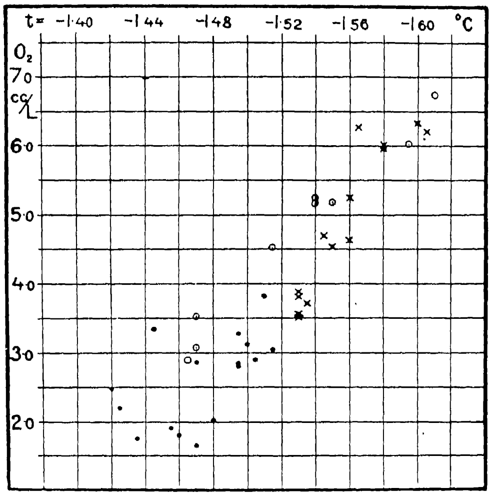

FIG. 10. RELATION BETWEEN THE OXYGEN-CONTENT AND THE TEMPERATURE OF WATER OF SALINITY 32 TO 33 PARTS PER THOUSAND.

oscillates back and forth, leaving the shelf in the summer and returning in the fall. It is possible that this variation is connected with the outpour of great masses of fresh water from the large rivers, but our observations from this region are extended over one year only and we, therefore, do not know whether the same changes are repeated year after year. However, it seems clear that the bottom-water does not stay on the shelf for any very great period, but it flows occasionally to the north and entering the deeper part of the sea it becomes mixed with water from other regions and the physical and chemical properties are altered.

Our observations of the oxygen content indicate as already emphasized that the original amount of oxygen is consumed in the periods while the water is on the shelf. Our temperature observations show that the temperature of the water rises simultaneously. The simultaneous observations of oxygen content and temperature have been plotted in Fig. 10, from which it is evident that a high temperature always is associated with a low oxygen content, and *vice versa.* This fact points strongly in the direction that the bottom-water is heated at the same time that it is deprived of its content of oxygen. Other observations point in the same direction, but we will confine our attention to the relation between the oxygen content and the temperature which is represented in this figure as a sufficient proof for the assertion that the bottom-water is heated on the shelf and that the total rise in temperature amounts to about 0.2°. The next question which arises is from what source does the heat that causes this rise in temperature originate? An estimate of the heat which is liberated by reason of the chemical action which reduces the oxygen content and increases the content of carbonic acid gives values far too small to account for the changes in temperature. The same applies to an estimate of the heat which is generated because part of the kinetic energy of the currents is dissipated on account of frictional resistance along the bottom. The only other source to be considered is the heat which is supplied to the bottom from the interior of the earth. It is a well-known fact that the temperature of the earth increases with depth, and several authors have computed the amount of heat which on account of this temperature rise is conducted to the surface, or to the bottom of the sea, in one year. The figures vary between sixty and one hundred gram calories per square centime-

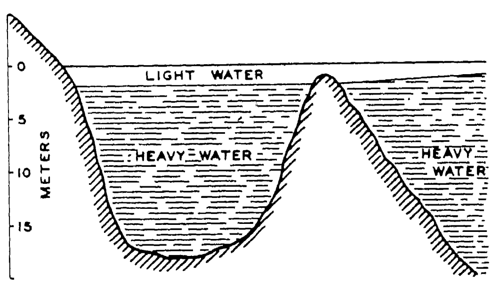

FIG. 11. SCHEMATIC REPRESENTATION OF THE STRATIFICATION OF WATER IN AN OYSTER BASIN. THE HORIZONTAL SCALE IS ARBITRARY.

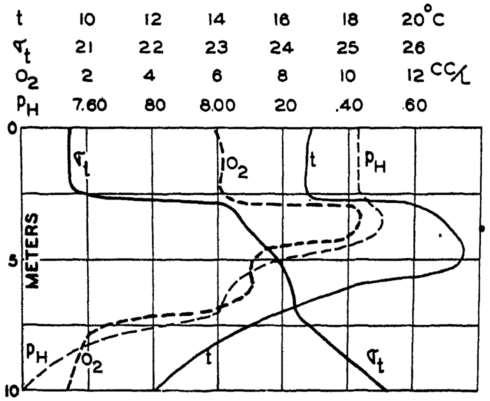

FIG. 12. VERTICAL DISTRIBUTION OF TEMPERATURE t, DENSITY σ_t, OXYGEN CONTENT O_2 AND HYDROGEN-ION CONCENTRATION pH IN AN OYSTER BASIN, SEPTEMBER 6, 1914.

ter, and these quantities would raise the temperature of the bottom-water, which has a thickness of only five meters, by one to two tenths of a degree in one year. A rise of this magnitude seems actually to take place, and it is therefore indeed probable that the observed conditions are to be explained on this basis.

The effect of the heating from below on the temperature of the bottom-water has been discussed by several oceanographers, but at present only one example is known which clearly demonstrates such an effect. This example is based upon observations from the Philippine Deep, which is isolated from the neighboring seas by submarine ridges. Only the upper layers of the water in this basin are in communication with the adjacent sea, while the deep water from 5,300 meters to the bottom is stagnating. Within this deep water the temperature rises towards the bottom at a greater rate than should be expected from the effect of the adiabatic heating, and this rise has been ascribed to the heating from below. In the open oceans, where even the deepest waters take part in a slow circulation, no such effect can be detected because the temperature changes which are brought about in connection with the circulation are far greater than those which are due to the heating from below. The conditions on the North Siberian Shelf are outstanding because of the pronounced stratification of the water. However, we could not have discussed the problem had the temperature observations not been accurate within a few one-hundredths of a degree.

The heating of the bottom-water has been treated at some length in order to demonstrate the importance of the boundary layers and to show that these effectively cut off any transfer from the neighboring layers. It is not difficult to find other examples which illustrate the effect of the boundary layers.

In the oyster basins of western Norway we find very outstanding conditions. These oyster basins communicate with the sea through narrow and very shallow inlets. The depths of the basins may vary from ten to twenty meters, but the inlets are so shallow that the thresholds lie dry at low tide. The surface water in a basin has a low salinity on account of admixture of fresh water from brooks, but the water below a depth of about two meters has the same salinity as the coastal waters outside of the inlet because this water occasionally overflows the threshold and fills the inner basin. We thus find a typically stratified water in the basins and a critical boundary surface lying only two meters below the surface, as represented schematically in Fig. 11. Remarkable conditions develop in summer on account of this stratification. The upper layer of light water is heated by the radiation from the sun, but the mean temperature of this layer can never rise above the temperature of the air, because this layer is in contact with the air and gives off heat to the air as soon as it gets warmer. However, the radiation penetrates to considerable depths before being completely absorbed. The heavy water be-

low two meters is, therefore, also heated and in this layer the heat accumulates during the whole summer, since the water remains always much heavier than the surface water on account of the great difference in salinity, and the boundary surface remains very sharp, for which reason no heat is given off to the layer above. As a consequence of the continuous heating in summer the temperature of the heavy water rises much above the air temperature. In July and in the beginning of August, before the loss of heat by nocturnal radiation has begun, temperatures as high as 25° to 30° have been observed in these basins. At these temperatures the conditions for the development of organisms is very favorable and we find a rich life in the upper part of the heavy water.

In Fig. 12 the vertical distribution of density, temperature, oxygen and hydrogen-ion concentration is represented for one oyster basin at the beginning of September. The maximum temperature was at that time 21.5°. In the upper part of the heavy water we find very great quantities of oxygen, indicating that phytoplankton producing oxygen during processes of assimilation is abundant. The extremely high hydrogen-ion concentration points in the same direction. Approaching the bottom both quantities decrease rapidly, indicating that the decomposition of organic substances or the respiration of animals is dominating, because in both these processes oxygen is consumed and carbonic acid produced.

The oysters find very favorable conditions for their development in the upper part of the heavy water, where the temperatures are high and plankton present

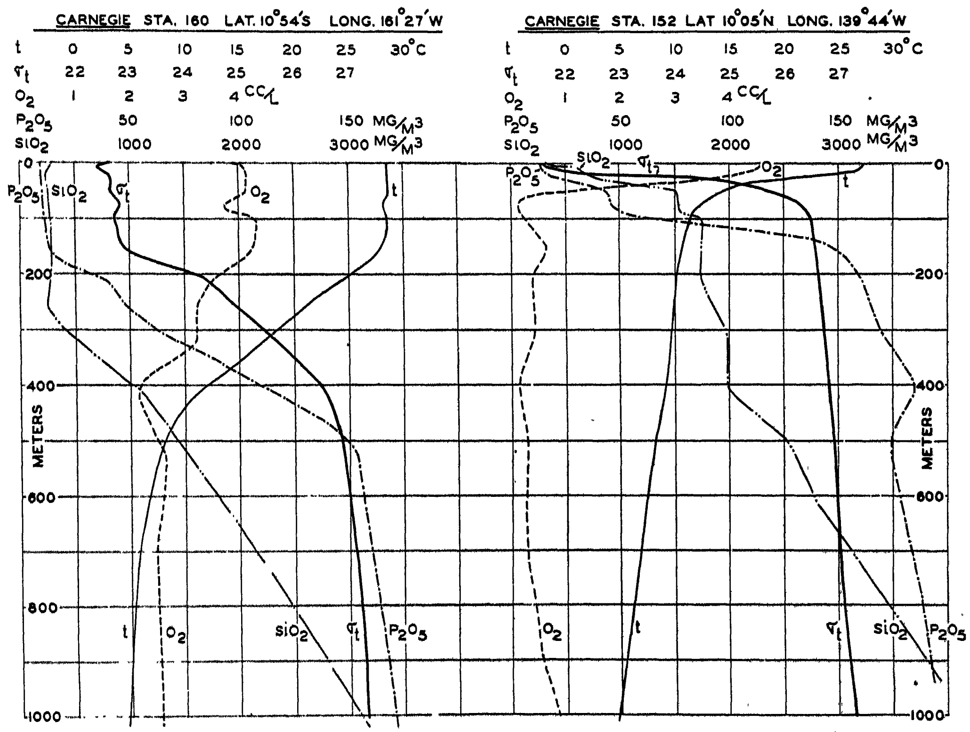

FIG. 13. Vertical distribution of temperature t, density σ_t, oxygen O_2, phosphates P_2O_5 and silicates SiO_2 at the *Carnegie* stations Nos. 160 and 152.

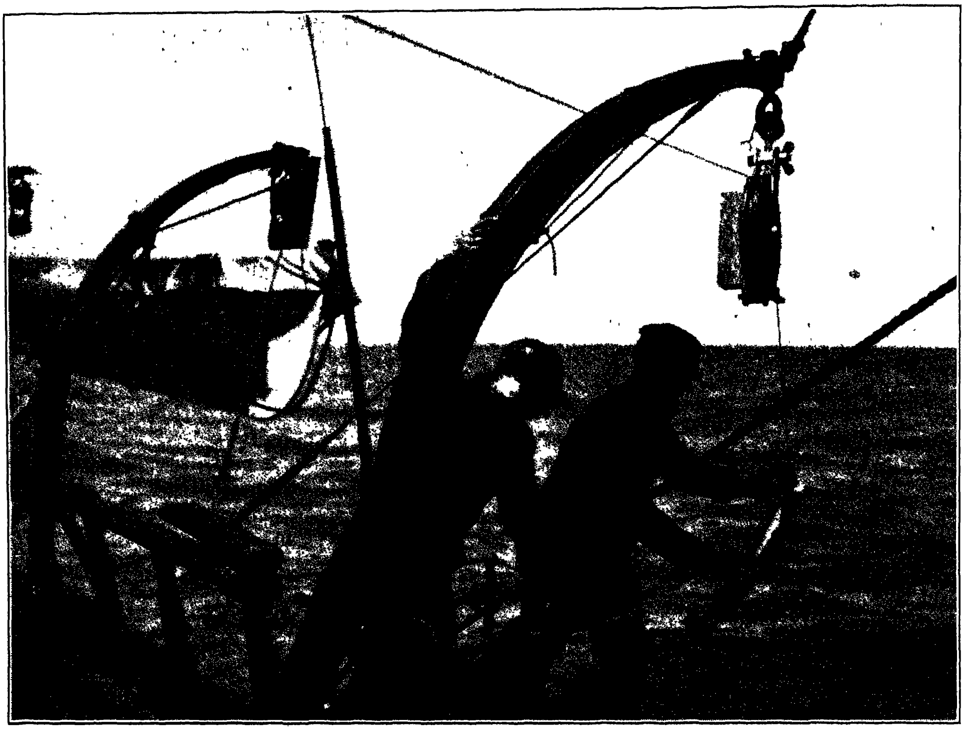

FIG. 14. REMOVING WATER-BOTTLE
AT *Carnegie* STATION IN PACIFIC OCEAN. NOTE METER-WHEEL FOR MEASURING LENGTH OF CABLE.

in great quantities. However, it is of interest to mention, according to recent investigation, that the water is practically free of the essential substances, nitrates, phosphates and silicates, because these have been used by the minute organisms as soon as they have been supplied to the water. The lack of these substances apparently handicaps the development of the oyster-spats, and promising experiments pertaining to supplying the water with these fertilizing substances during the period of spawning have recently been carried out.

One might believe that such remarkable discontinuities as those demonstrated in these two examples are found only in coastal waters where great contrasts may be expected to occur. However, similar discontinuities are met with also in the open ocean, and the condition for development of organisms must, therefore, be widely different in different regions. Observations from the central part of the Pacific Ocean which were obtained on board the *Carnegie* are extremely well suited for illustrating this assertion. The vertical distribution from the surface to 1,000 meters of temperature, density, oxygen, phosphates and silicates at two stations is represented in Fig. 13. The station to the left is located in latitude 10°54′ south and longitude 161°27′ west; the station to the right in latitude 10°05′ north and longitude 139°44′ west. The vertical distribution at the left-hand station, No. 160, can be regarded as representing the normal conditions of tropical waters. The temperature of the water is high, above 28° C. down to a depth of about 150 meters, and the density is practically constant down to this depth. As a consequence the eddy conductivity within

this layer must be great, and this conclusion is confirmed by the fact that the oxygen content remains great to the depth of 150 meters. The conditions for the development of organisms must be favorable down to this depth, and we actually find very small amounts of phosphates and silicates because these substances have been used for building up organisms. Regarding the variation of the content of oxygen, phosphates and silicates below 150 meters, it may be remarked that this depends upon at least three factors, namely, the presence of living organisms, the decomposition of organic substances and the transfer from neighboring layers on account of eddy conductivity.

At the other station which has been selected for illustration, Station 152, the conditions are entirely different. The surface layer with high temperature and low density has here a vertical extension of less than twenty-five meters, and even at a depth of fifty meters the conditions for the development of organisms must be very unfavorable because the water in this depth is shut off from any supply of oxygen on account of the rapid increase in density which reduces the eddy conductivity to a minimum. The oxygen content actually decreases to practically nothing at seventy-five meters, and the relatively high content of phosphates and silicates in this depth indicates that only a small amount of the available quantities has been utilized for building up organisms. There is thus a striking difference between the conditions at these two stations. The very pronounced stratification at Station 152, which is of dominating importance to the possibility for the development of organisms, is probably due to an upwelling movement of the deep water. Such upwelling movement is well known off the coasts of California, Peru and Chile, but I am not aware of corresponding examples from the open ocean.

It is evident that remarkable horizontal currents must be present when the vertical distribution of density changes so much in a short distance as illustrated by the diagrams. On October 25, the *Carnegie* lost 4,100 meters of wire, nine water-bottles and eighteen thermometers, because the wires became entangled and broke. Referring to this misfortune Captain Ault says in a radio message dated November 1, "From dynamic computations the counter-equatorial current is a mighty river in the Pacific Ocean, flowing eastward thirty miles per day on the surface near its northern boundary, 8° north, with no velocity at 200 meters. No wonder our fishing lines became entangled in such a river."

The preceding discussion of the importance of the eddy conductivity has been confined to qualitative considerations of the effect of boundary surfaces upon the transfer which is due to the eddy conductivity. However, in order to arrive at more definite conclusions a quantitative knowledge of the eddy conductivity is desirable. Such knowledge can be obtained by means of theoretical investigations, supposing that the available observations allow a comparison between the theoretical results and the actual conditions. The writer was able to show that the current measurements on the North Siberian Shelf had permitted the calculation of some numerical values of the eddy viscosity, and other values have been derived from other observations, although under less pronounced conditions. The thermal conductivity, which was disregarded in order to avoid making a complicated subject more complicated, has been computed independently by three different investigators, namely, McEwen, of the Scripps Institution in California; Jacobsen, in Copenhagen, and Fjeldstad, in Bergen, and these three have arrived at very nearly the same numerical val-

ues, ranging from 1 to 20 in centimeter-gram-second units. These numbers represent the coefficient of thermal conductivity in sea-water if no very marked boundary surface occurs and are from 1,000 to 10,000 times greater than the thermal conductivity under laboratory conditions. Our knowledge of the conductivity of sea-water has been much advanced by the contributions of these investigators, and their works open promising prospects for the future.

Concluding, it is to be emphasized that only one side has been treated of the problem which deals with the conditions for development of organisms in the sea, namely, the vertical transfer of essential substances from one water layer to another on account of eddy conductivity. In case of a comprehensive discussion one would also have to consider a number of other factors which are studied by the physical oceanographers, for example, the seasonal variations of the stratification of the water, the variations in temperature, the horizontal and vertical transport of water by means of currents and the penetration of light into the sea. This enumeration may give an idea of the intimate contact among the various fields of research within oceanography and the importance of correlating the results of widely different investigations in order to gain a knowledge of the sea which may satisfy our desire for information and form a sound basis for application to the numerous problems dealing with the utilization of the quantities of food which are available in the sea.

THE RANGE OF HUMAN CAPACITIES

By Dr. DAVID WECHSLER

WHEN we compare the mathematical genius of an Einstein or the scientific intuition of a Pasteur or the poetic gifts of a Shakespeare with the correlative abilities of the average man, let alone those of the moron or idiot, the range of human capacities appears well-nigh limitless. Flattering, however, as these summits of human achievement may appear to our vanity, they nevertheless represent only isolated peaks; actual measurements of the distances which separate the masses of mankind from one another, along any capacity we might choose to compare them, are extremely small. Indeed, not only are the differences relatively small, but what is more striking, the ratio between the extreme limits of the capacities maintains a constancy which, as I shall presently show, is nothing short of remarkable.

My interest in the problem of the range of human capacities was inspired by the early observations of Professor Cattell, who remarked that the range of a number of mental abilities, as measured by various psychological tests, approached roughly the ratio of 1:2. I was so struck by the possible importance of this observation that I decided to investigate its validity, and to see whether it held for only a few isolated psychological abilities, or whether it applied to the entire range of human capacities. The evidence which I present in this paper is the result of several years' intermittent analysis of available data.

The investigation of the problem presents several difficulties. The first and most important one is the paucity of reliable data. This is particularly true in the case of mental measurements, the plethora of psychological testing since the introduction of the Binet intelligence tests, notwithstanding. It might surprise you to learn that until very recently there was no single study giving complete reaction-time measurements on as many as one hundred unselected individuals, although the reaction-time experiment was one of the first to be perfected in Wundt's laboratory. There have been published scores, one might say hundreds, of investigations, but in nearly every case the experiments were performed on half a dozen or a dozen subjects, usually university students, each with a distinct technique and not otherwise lending themselves to comparison.

In addition to the problem of the insufficiency of the number of cases and of the selected character of the population studied, one further encounters the difficulty of having summarized rather than fully presented data. What is needed for an analysis of the range of variability is a complete presentation of the original measures, that is, the total distribution of data selected. Until recently, however, most authors were content to publish merely measures of central tendency, whether average or median, only rarely including measures of dispersion and, indeed, often omitting to state unequivocally the total number of cases studied. Finally, in mental measurement we are confronted with the problem of the comparability of our units of measurement and of the location of the true zero point. If one is comparing, for instance, body weight, one can say that the man of two hundred pounds weighs twice as much as the one of one hundred pounds, but it is quite a different thing to assert that the child who solves four problems correctly has twice the mathematical ability of the one who

solves only two, or even to say that the first child can work twice as fast, unless we can be sure that the problems presented are of equal difficulty. The difference implied in the two illustrations is one which might be summarized by saying that in the first case we are dealing with natural, or at least equivalent, units, and in the other with arbitrary, or units of uncertain equivalence. The latter must first be equated before quantitative comparisons can be made, and as this has seldom been done in psychological measurements, particularly those which purport to measure various kinds of achievement, much if not most of the data otherwise usable does not lend itself to the comparison of the kind we have proposed for our present investigation.

In spite of the difficulties just enumerated, however, which make so much of the published anthropometric and psychological measurements unusable, I was able to find a goodly amount which can be trusted, and I shall, without much further ado, present the results which these data reveal as regards the method of measuring this range. The aim is to see how the highest or best individual compares with the lowest or poorest individual in any given ability. We shall thus have to compare the performances or measurements of the very extreme cases actually recorded. Now, aside from the fact that these extreme measures are generally not available because complete distribution of the measures is seldom given, the actual recorded extremes are generally not the most reliable cases to take. For if we did, we might thus, in the case of measuring cranial capacity, for example, have to include instances of hydrocephaly; or again, in studying visual acuity, individuals who are on the way to becoming blind, and so on. *A priori*, one would say that we have no right to reject any case. But it must be obvious that we are merely doing violence to our notion of variability by including individuals that are clearly pathological, or in other ways accidental cases.

In a like manner, when studying the range of variation in mathematical ability, we ought theoretically to include a Gauss or a Newton on the one hand, and a vegetating idiot on the other. But here again, I am inclined to look on both these extremes as sports, the latter unfortunately more frequent than the former, but still relatively sporadic occurrences. At any rate, I shall claim for the statistics that I am about to present that they apply only to the mass of mankind, that is, if you will, to 998 out of every 1,000 individuals. Our task then ought to consist of comparing the 2nd with the 999th individual in every 1,000.

Many of the data from which I have drawn my conclusions do not include as many as 1,000 cases, but we can readily calculate by proper statistical methods what the value of the 2nd and 999th cases would be from our obtained measures, and often with greater reliability than if we had the actual figures. For, if we know the mean and standard deviation of our measured distribution, we can readily obtain the theoretical value of the 2nd and 999th case by first subtracting and then adding three times the standard deviation to the mean, since six times the standard deviation includes approximately 99.7 per cent. of the cases. It is this method which I have generally used in obtaining my extreme measures. The assumption which has to be made is that the distribution of the measures of the trait in question is normal—an assumption which we know holds for most biological traits and which I have verified wherever possible in these traits which I have included in my study. In any case, the errors which might be introduced if the assumption we have made does not hold would all tend to vitiate rather than to confirm the con-

stancy of the ratio revealed. There is little doubt that the range of capacities if calculated from more complete data would reveal an even greater constancy than my present figures show.

Let us now examine the figures themselves. I have, for convenience, classified the available data under four groups: measures of physical, of physiological, of psychomotor and perceptual and, finally, of mental capacities. These are given in Table I arranged in the order just enumerated. The first column gives the source or compiler of the figures, together with the number of cases in which the measurements were made; the third column, the mean; the fourth the standard deviation; the fifth the range as calculated, namely, $\frac{M + (3 \times S.D.)}{M - (3 \times S.D.)}$; the sixth the numerical value of this ratio. In some instances the mean and standard deviation were not available and here actual extremes as furnished by the author are given in their stead. Many of the values presented in the table have been calculated from the raw data.

The table here presented, while not exhaustive, comprises by far the largest part of the data available, at least such as are published in English. It were highly desirable that fuller data were at hand; this lack, among other things, calls attention to the urgent need of a systematic remeasurement of the fundamental capacities of man, and it is to be hoped that one or another of the foundations that are interested in the study of human relations will make this investigation possible in the near future. The data, however, such as they are, nevertheless do permit us several generalizations which, I believe, augmented and improved data will only substantiate and reaffirm in more precise terms.

The first and fundamental conclusion

TABLE I
THE RANGE OF VARIOUS HUMAN CAPACITIES*

Source and no. of cases	Trait or capacity	Mean	S.D.	Range	Ratio
Galton (4,098)	Weight of body	148.9	20.23	209–88.2	2.29: 1
Rezius (416)	Weight of brain	1400	106.3	1719–1181	1.45: 1
Greenwood (302)	Weight of heart	11.04	1.92	16.8–7.3	2.30: 1
Macdonell (80)	Cranial capacity	1476	122.4	1843–1111	1.66: 1
Galton (4,098)	Strength of grip	74.6	12.51	112–37.5	2.99: 1
Alvarez (1,066)	Blood pressure	130.0	13.4	170–89.8	1.89: 1
Goring (500)	Pulse rate	74.2	11.02	107–43.2	2.48: 1
Galton (4,098)	Vital capacity	221.8	39.0	339–104	3.23: 1
Korosy (253)	Respiration rate	15.84	2.35	22.9–8.8	2.60: 1
Lemon (113)	S. reaction-time	199.1	25.50	276–123	2.24: 1
Galton (4,098)	Audible pitch	3586	492	5062–2110	2.40: 1
Woodworth (100)	Snellen acuity	1.74	....	2.54–1.00	2.54: 1
Terman (905)	Intel. quotients	100.7	12.02	136–64.6	2.11: 1
Burt (200)	Binet mental age (both sexes, age 9)	9.4	1.24	13.1–5.7	2.30: 1
Gates (197)	Memory span	7.5	....	11–5	2.20: 1
Mean					2.31: 1
Median					2.30: 1

* Adult male, unless otherwise indicated.

is that the range of human capacities, at least as they pertain to the mass of mankind, is relatively small. Secondly, that the limits of most human traits, when measured in comparable units and from true zero points, may be approximately expressed by the ratio of 2:1. Thirdly, that this ratio recurs so frequently and over so wide a range of traits as strongly to suggest that we are here dealing with a natural psychobiologic constant.

The figures upon which our generalizations are drawn actually only approximately bear out this ratio. It does not, to be sure, have the absolute mathematical constancy of the relation of the radius of a circle to its circumference. But when we consider the numerous causes of error to which the measures upon which they are based are liable, and even more when we consider the almost infinite numerical relations which might *a priori* have obtained between the limits of the measured ranges, I think it is rather remarkable that these limits can be expressed by such small numbers, and that these numbers so nearly approach the ratio indicated. My belief is that we are certainly dealing with what in the more precise sciences is defined as a natural constant.

From the statistical point of view, the relations established, even if only approximate, are extremely important, because they help in a way to prognosticate the range of yet incompletely measured traits or of such as are yet to come under observation. For if our generalization as regards the variability of traits is correct, we know in advance that it is extremely unlikely that any individual will be found that will measure more than twice as much as the smallest case, or less than half of our largest, however small the sample of population upon which our observations have been made. Indeed, the validity of the descriptions of a large part of physiological investigation, which generally involves inferences drawn from a relatively small number of cases, really depends upon the fact that this assumption holds.

In concluding, it is not without interest to call attention to some rather important social implications which the results of this study seem to carry with them. One of the most persistent arguments of those who are opposed to social control, whether in politics or in industry, is that such control together with the standardization of compensation or reward that goes with it must be very unfair to the individual. To take a specific instance, a standard union wage is much decried because the superior and inferior worker are given equal compensation. If the range of capacities is as narrow as our ratio indicates, the injustice can not be very great and certainly not to very many individuals in the total population.

That the variations in individual efficiency are not very great, when taken in the large, is revealed by a comparison of the actual outputs of individuals engaged in diverse occupations. A series of such comparisons taken from Hull is given in Table II. The average range in variation of capacities is here as before approximately 2:1; that is, the most efficient individual does not produce more than twice as much as the least efficient. And if we remember that the figures give the ratios of the very extremes and that by contrast most individuals are grouped about the mean, the differences in efficiency which separate the mass of individuals in any given occupation from another can not be very great.

Perhaps an even more vital implication is the one that bears on the current beliefs as regards racial differences. Scattered studies, especially in this country, have given rise to the belief in the existence of varying degrees of superiority and inferiority among different national groups. What these studies have

TABLE II

RATIO OF MOST TO LEAST EFFICIENT INDIVIDUAL ENGAGED IN DIFFERENT OCCUPATIONS§

Source	Occupation	Criterion	Ratio
Lovejoy and Monroe	Heel trimming (shoes)	Number per day	1.4: 1
Elton	Loom operation	Per cent. of time loom kept working	1.5: 1
Pollock	Hosiery maters	Hourly earnings	1.9: 1
Wyatt	Loom operation	Earnings	2.0: 1
Lovejoy and Monroe	Bottom scoring (shoes)	Number per day	2.0: 1
Pollock	Machine operators	Hourly piece-work	2.2: 1
Farmer	Polishing spoons	Time per 36 spoons	5.1: 1
Median			2.0: 1

§ (Abbreviated, from Hull.)

revealed are certain measurable trait or capacity differences, but those who have made use of them have almost altogether failed to appraise the significance of these differences. For certain purposes it may be useful to know that one group attains an average intelligence quotient of 87 and another of 92, but, from a social point of view, even more important is it to evaluate what such difference means. It is important, for instance, when you are grading school children, but practically negligible when you are comparing human beings. The comparison that may then have to be made is not between John Smith, IQ 87, and Tom Brown, IQ 92, but between John Smith, *Homo sapiens,* and the missing link, *Pithecanthropus erectus.*

This implication has generally been disregarded, and the tendency in recent years has been rather to exaggerate and overemphasize human differences, whether in the field of psychology, government or industry. Everywhere the search has been for experts or dictators, on the assumption that among all groups there is an inevitable minority so superior to the rest of the population that they alone are capable of ruling over and thinking for the group. Now every democracy and particularly our own is based on the very contrary assumption; and if the facts we have brought forward are at all correct this assumption is entirely justified, for the differences between men, when the totality of the capacities is considered, is surprisingly small. I do not thereby mean to imply that these differences are insignificant or that, however small, they may not be extremely important for practical purposes. The capacity of a man who can jump six feet one inch exceeds by only one thirtieth that of another who can jump five feet eleven inches, but it may mean the difference between life and death if the leap required be across a six-foot chasm. Still, it is well to recall that the distance which separates the victor from the victim is often no greater than the breadth of a hair.

GEOGRAPHY OF AMERICAN MAYORS

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ALTHOUGH mayors rule over a very large percentage of our people, have great social prestige and wield great power, they appear to have been subjected to no geographic statistical analysis. In the hope that some interesting facts might come to light, data concerning one hundred mayors of twenty-seven large American cities were gathered from "Who's Who in America." The mayors selected were all the recent ones sketched for the larger cities of the several chief sections of the country, Northeast, Midwest, South and Pacific. Of course large cities having the city-manager form of government have no mayors and are not represented. The facts gathered from "Who's Who" were those of birthplace, education—extent and where obtained—whether or not the mayor served more than one term, politics.

The hundred mayors studied include nine from Philadelphia, eight from New York, seven from Boston, six each from Detroit and Louisville, five each from Pittsburgh and Milwaukee, four each from Baltimore, Chicago, Minneapolis, New Orleans, San Francisco, Seattle, St. Louis and St. Paul, three each from Buffalo, Indianapolis and Newark, two each from Los Angeles, Portland (Oregon), Richmond and Toledo and one each from Denver, Grand Rapids, Jersey City, Memphis and Oklahoma City. In every case all the more recent mayors sketched in "Who's Who" were included, except one who did not give his birthplace.

Among the various sections of the country the distribution of the mayors studied is as follows: Northeastern cities, 36 mayors; Northcentral cities, 33 mayors; cities west of the Mississippi River, 26 mayors; Southern cities, 18 mayors; Pacific cities, 12 mayors.

Of the hundred mayors, 43 were Republicans, 39 were Democrats, 3 were Socialists and 16 did not specify their political affiliation or were "independents."

Of the hundred mayors, twelve, or one eighth, were born in foreign lands, one having been born in Canada and the others in the British Isles, Germany or France. Most of the eighty-eight native-born mayors were born either in the city of which they were mayor or near by. Thirty-eight were born in the city itself, thirteen in a suburb of the city. Forty-eight came less than 25 miles from their birthplace to the city of which they were mayor; six came between 25 and 100 miles; eight came 100 to 200 miles; another eight came 200 to 500 miles; five came 500 to 900 miles; one came from New York to New Orleans, 1,170 miles, and seven mayors of Pacific coast cities came from the Middle West or East, distances of 1,500 to 2,500 miles. Eleven came from Europe, distances of 3,000 to 5,500 miles.

Fourteen of the mayors were born in the state of their mayorship, but at some distance from the city. About one fourth (twenty-three) were born in another state.

Only one of the hundred mayors stated specially that he was born on a farm. Six gave their birthplace as a county without mentioning a town. Presumably most of these were born on farms. Some who gave their birthplace as a town probably were born on a nearby farm. But it is apparent that the mayors were predominantly city-bred. When most of the mayors were born, more than three fourths of the

people lived on farms. Yet of the eighty-eight native-born mayors, forty give their birthplace as a large city, thirteen as a suburb of a large city, seven as a small city and twenty-three as a town or village.

Cities of which all the recent mayors sketched in "Who's Who" were born in the city of which they were afterwards mayor, or a suburb thereof, are: Baltimore 4, Buffalo 3, Louisville 6, Richmond 2, Jersey City 1 and Memphis 1. Cities of which none of the recent mayors sketched in "Who's Who" were born in that city or a suburb thereof are: Los Angeles 2, Indianapolis 3, Minneapolis 4, Seattle 4, Toledo 2 and the following with one mayor each, Denver, Grand Rapids, Oklahoma City.

One of the surprising facts about the geography of the birthplaces of these hundred mayors of leading American cities is that they were, almost without exception, not appreciably to the westward of the city over which the mayor later ruled. The advice, "Go West, young man," seems to have been followed by almost all the young men with political ambitions who struck out to seek their fortunes elsewhere. Or, possibly, the voters have looked askance at the men who came out of the "less advanced West." At any rate, out of the hundred mayors only two came eastward as much as thirty miles to become mayor, and only one came over sixty miles. He came from Ohio to Philadelphia. It is surprising that central and western New York, the birthplace of five mayors for other more western cities, should have yielded none for New York City itself, out of the last eight. Indeed, only one of the eight went eastward more than twenty-five miles to New York; he went sixty miles.

Nineteen of the twenty-one cities electing mayors some of whom came from elsewhere chose men who had come from the East. Boston took a man born in Maine, and one in Ireland; Chicago took two born in Boston (including the notorious Thompson, of anti-British fame) and one in Connecticut; Detroit one born in Pennsylvania and one in Ontario; Minneapolis one born in Wisconsin and one in Scotland; St. Louis one born in Illinois; St. Paul one each from Indiana and Germany; Oklahoma City got its mayor from Arkansas.

As might be expected, most of the mayors of Western cities were born in the East. Seattle's four came from Iowa, Tennessee, Massachusetts and England; Portland, Oregon, got one from New York; Los Angeles' two came from Wisconsin and Nebraska; San Francisco elected one from Illinois and another from Ireland.

Two Southern-born men became mayors of Northern cities, Tennessee yielding one to Seattle and Kentucky one to Denver. Only one Northern-born man of the hundred was a mayor of a Southern city, a native of New York City who was mayor of New Orleans. But all three of these men migrated westward as well as north or south.

Of the twelve foreign-born mayors of the one hundred, Ontario, Canada, yielded one to near-by Detroit, Scotland one to Minneapolis, France one to New Orleans, Wales one to Toledo, England two (Philadelphia and Seattle), Germany three (New York, Philadelphia, St. Paul) and Ireland three (Boston, Indianapolis, San Francisco).

Hence of New York's eight mayors only one was foreign-born (German); of Boston's seven, one was Irish, while of Philadelphia's nine one was German and another English.

Of course it may be accidental, but nevertheless it is interesting to note that Chicago, with 30 per cent. of its population foreign-born in 1920, has had no recent foreign-born mayor, and Boston with 32 per cent. of the population foreign, and New York with 35 per cent.,

had only one each, while Philadelphia, "The city of friends," with only 24 per cent. foreign-born, has had two, as well as being the only city which elected recently a man from a more western state. Two of the cities who have had foreign-born governors recently, Indianapolis and New Orleans, have only a very small percentage of their population foreign-born (5 to 7 per cent.), while the others have a percentage close to that of Philadelphia, approximately 24 per cent.

The yield of the eighty-eight native-born mayors by states yielding four or more is as follows: New York thirteen, Pennsylvania eleven, Massachusetts eight, Kentucky seven, Wisconsin six, New Jersey five, Michigan five, Maryland four. In proportion to population at the 1860 census, the census nearest the average date of birth, these states rank, however, quite differently, to wit: Wisconsin, New Jersey, Michigan, Massachusetts, Kentucky, Maryland, Pennsylvania, New York. Kentucky's high rank is partly explained, doubtless, by the fact that six mayors of Louisville, all born in Kentucky, are included. Likewise Maryland supplied mayors only to Baltimore. The states which furnished most mayors to other states, in proportion to population, were Wisconsin, Massachusetts, New York and Pennsylvania.

Forty-one of the one hundred mayors graduated from college or university, and six others attended without graduation. It therefore is apparent that the mayors of the larger American cities had much more formal education than their electorate, for less than 1 per cent. of the older voters of these large cities are college graduates and only a small percentage are high-school graduates. Four fifths of the college graduates attended college in the state in which they were afterwards mayor. Only one eighth of the one hundred mayors, including some who did not graduate, attended college in another state than that in which they were mayor. Twelve of the one hundred mayors received advanced degrees, four of them from institutions in other states. Nearly all who did not attend college mention graduating or attending high school, in two thirds of the instances in the state where they were afterwards mayor. The geography of the ratio between the number of mayors who were college graduates and those who were not is of interest. Six of New York's eight mayors were college graduates and another attended college. Seattle had three college graduates to one not graduating; Boston 3:4; Chicago, Minneapolis and San Francisco 2:2; Louisville 3:3; Milwaukeee and Pittsburgh 2:3; Philadelphia 3:6; Indianapolis and Newark 1:2; New Orleans, St. Louis and St. Paul 1:3, and Detroit 1:5.

Of the one hundred mayors, forty-two have already served more than one term.

THE ULTIMATE INDUSTRIALISM

By C. C. FURNAS

U. S. DEPARTMENT OF COMMERCE

PLATO'S "Republic," Sir Thomas More's "Utopia," Edward Bellamy's "Looking Backward" and H. G. Wells's assortment of "Men Like Gods" and places like heaven all point the way to the dreamland of the socially minded, but none of them bother with the details of the means of doing the world's work in a very few hours per day so that there may be time for the ideal society to function. Now that the engineers are steadily paring down the time that it takes to do everything and are giving us the physical equipment for the realization of such dreams, the crop of Utopia makers and optimists seems to have passed away. It would appear, then, as if it were legitimate for the private individual to amuse himself with speculations concerning the welfare of the people many generations removed, regarding the lack of social injustices and the prevalence of leisure, well-being, happiness and culture, basing the estimate upon a liberal extrapolation of the mechanistic possibilities of industrialism as we now know it.

Looking ahead to the n^{th} century we may expect to see a civilization wherein the drudgery of the working day will last, on the average, but two hours. (The figure two may be too large; it makes but little difference as long as the amount involved is small.) The average job will require practically no skill or intelligence and will consist principally of actuating various forms of push buttons or levers. That part of the population which works will be urban or, at the farthest, suburban. The food makers will be the last to move in from the soil and do their work in vats and kettles. Whether the hog raisers, the corn growers or the lettuce and spinach people will survive the longest we can not hazard a guess as yet.

The cities will be more numerous but of reasonable size. Even with modern transportation many of the present cities admittedly are too large; the congestion is irritating and makes for inefficiency. Probably a thorough analysis would show that the tendency to concentrate as many people as possible in one place is due more to commercial fads than to economic expediency. At this time, to have proper standing, you must be "within an hour of New York," and standing is about all you do.

Soot for the collar and cinders for the eye will long since have passed away, except possibly for the few caretakers at the gas works. All the places of manufacture will be at least as attractive as the average college campus, as they are even now in a very few instances.

The people will be fewer than at present. Let us hazard our reputation for figures and say that the cut in population will be one half. This will leave enough to keep the tigers down to a reasonable figure in Burma and fishing will be ever so much better. The open spaces will be more frequent and more open but still much more accessible for vacationists. Probably a cog road will run to the top of Mount Everest.

After each person (both sexes) has finished his routine education at, say, twenty-five years of age, he will stand in debt to the world for a given amount of labor. He may enter the employ of one of the large corporations for the purpose of working off the required amount of drudgery as painlessly as possible. He may sign a contract to do as the company bids for a certain number of hours, say ten thousand. In return the com-

pany will agree to pay a specified sustaining wage for the individual's entire life. The employee will be given the choice of a number of policies for delivering his labor. He may:

(*a*) work two hours a day for twenty years
(*b*) four hours a day for ten years
(*c*) eight hours a day for five years
(*d*) four hours a day for six months of the year for twenty years
(*e*) eight hours a day for three months of the year for twenty years
(*f*) etc., etc.

All this looks as if it were taken from an insurance actuary's note-book. Each average individual will contribute to the world's drudgery and will receive the assurance of the necessities of life in return, and when his obligation has been met he may go sauntering on his way to waste the most time in the most enjoyable manner. The policies for work will be "ordinary life, twenty pay life with or without leaving the dividends in, ten year endowment"—any of the infinite varieties an ingenious man can think of.

We see a faint glimmer of the wage assurance idea in the old age pensions for teachers, government employees and workers in many industries. In some instances, even now, it is not necessary to have arrived at the dignity of senility and decrepitude before receiving an official sustaining allowance—but it is only necessary to put in thirty years of service and then the faithful one may, if he wishes, retire on a portion of his current salary. A good man is just well started after thirty years of service, and a reasonable fraction of the best part of his expectant life is still before him. The tinge of the coming dawn begins to trim itself with rose and gold.

Even though it is opposed from many sources, the onward march of the shorter working day is with us. The recent labor rhyme

Eight hours work
Eight hours play
Eight hours sleep
Eight "bob" a day

is already antiquated for propaganda purposes. (It is only necessary to glance at the minimum wage stipulated in the last line to see that the jingle came from no American mind.) Certain of the railroad brotherhoods are now campaigning for the six-hour day so that more people may have work. The shortening day continues—banking hours from ten to two, and prize-fighters, thirty minutes a year. The best socialistic propaganda has long specified that four hours a day would be sufficient if every one worked. We may well look askance at the figure for present practice, and we will only file it away and look in upon it in future years.

The average man now works from one half to two thirds as long as did the laborer at the beginning of the industrial era, but he produces many times as much as in the former period—more shoes, more beans, more plows. What becomes of the greater production? We use more things; we use automobiles, radios, tooth-brushes, spinach, electric lights, soap and hot water. We travel more, have our hair marcelled and play golf, requiring twelve dozen balls, twelve clubs and a caddy. We have never completely satisfied ourselves that we have everything we need for our ultimate happiness. In our hearts we commit murder more often than adultery because of the regular march of salespeople "introducing" new oil burners, dish-washers, clothes cleaners, hair dyes, guaranteed contraceptives, insurance, doorknobs and water heaters, but still we keep buying. The end of the new is not yet in sight, but it may confidently be expected that before long business will begin to slacken if it has not done so already. There are entirely too many unemployed now, and unless some one shortens the working day or is able to make televisions and aeroplanes into household articles by next week conditions will grow steadily worse, and Mr. Hoover's manipulation of public works

can afford but temporary relief. Ultimately we shall lose the recourse of added products to offset the improvement of methods which is certain to continue.

Either, then, the working day must be shortened and the wages correspondingly increased, so that every one may be employed, or a goodly portion must be left to starve. For permanent social security only one choice is possible—the working day must be shortened. The Western world now knows that it is poor economy to have starving millions crying, "Bread! Bread!"

This process of shortening the hours will continue in the same way it always has: by the stench of industrial arguments. The prospects are, however, that the conflicts will become progressively less disgusting as time goes on, particularly if the present tendency to encourage employee ownership of stock expands as may be expected. Every time hours are shortened and wage rates correspondingly increased and more people are employed, those in command will lose a portion of the distinct material advantage they had held previous to the change. The one who profits will be he who previously was unemployed and to a smaller degree the man who receives the shorter hours. The two ends of the scale will always be in conflict, and even those people who believe in fairy-tales can hardly expect the arguments to be settled without bally-hoo and hard feelings.

England rose to great industrial prosperity on the existence of the bread-line which furnished an abundance of cheap labor. Until the enactment of the immigration laws of 1919 American industries were successful in maintaining an influxing stream of excess foreign labor which made life more profitable for the man at the top and more miserable for the one at the bottom. Captains of industry do not relinquish such advantages easily.

Even when the time comes for the most abbreviated day, those who are shrewd enough to be in command will have a great material advantage over those who labor. This advantage may or may not be as great as it is now. The relative level of fortunes of the leaders will fall with each general wage increase or cut in hours and will rise gradually as more efficient production is developed, only to be cut again through the annoying existence of labor arguments. It is very doubtful if any political or industrial monarch will be able to duplicate the criminal wastages of Louis XIV.

The character of the common workman will not change with the passage of time. He will grumble about the long hours (despite their shortness), the poor pay, the unreasonable boss and all those who have more money than he. He will be in very fortunate circumstances but will not know or acknowledge it. We do not dare to predict the exact economic status of those who live under the hump of the probable distribution curve. We can only be certain that they will not be satisfied.

No matter what the economic condition of the land may be, the indigent idlers will always be with us. No amount of economic opportunity or coercion can change such natures, and in our picture of the future we can not omit those to whom perpetual leisure is of paramount importance. They will be the ones for whom two hours of labor per day will be too many, the press of life will be too great, and so they will wander the lengths of the land watching for the morning's manna as the day begins.

The professional class, the business leaders, the able and the ambitious will still work long hours, or at least burn the light in the study until late at night for the benefit of neighborly observers.

The miserly but dull person without ability may be able to work out four

labor policies in a lifetime and draw quadruple annuities in his closing years and look with hauteur upon those who would come borrowing from an honest man. He may be able to do even worse than that and work out five policies, barring accidents and a disagreeable wife.

Numerous corollaries push up their inquisitive heads and bark for attention. Let us ramble with passing curiosity among communism, culture, leisure, education, material possessions, race, war, ethics, religion, length of life and purpose.

Permanent communism among creatures such as men probably will never be. There are too many individual differences, and in any organism as complex as the human, differences can not pass away even if the eugenists are given complete control and only the bluest blood allowed to survive. Undoubtedly there will be considerable socialistic control of the upper reaches of material wealth, but it is difficult to envision the permanent decadence of private property.

When we turn to culture we deal with a dangerous subject. It has started wars and broken up bridge clubs. Yet it is so closely allied with physical conditions that we can not pass it by.

The Greeks, in their palmiest days, were able to maintain, with economic stability, a society wherein on the average it was necessary to have only five slaves and some dishonesty in order to live decently in leisure and to acquire an acceptable culture. The prospects now are that in the future each individual will have untold quantities of bouncing electrons, a complete assortment of all varieties of electromagnetic waves, immense quantities of materials and a thousand horse-power at his command. Comparing his situation with that of the Greeks, he will be living in conditions infinitely more conducive to leisure and culture than any Greek ever thought about.

The classicist and the humanist sniff, "As if culture or genius were a matter of electrons or horse-power!" This is an excellent place to draw up and have words on this particular thesis. With due recognition of the gap between opportunity and realization let it be said unreservedly that opportunity for cultural advancement is always obtained by pressing into service either slaves (paid or unpaid, free or bound, just as you like) or horse-power. If, in a given civilization, the standard of living requires mechanical labor for ten hours each day and one man in six is an artist, who has no time left over from his letters, his fishing tackle or his canvas to engage in his allotted share of the drudgery, then the remaining five must work twelve hours of each day if society is to be kept on an even keel. Each of the five has been imposed upon by the artist to the extent of two hours' labor each day. Moreover, the laborer receives no benefit from his master's leisure for the higher things; twelve hours of labor makes a man too tired, he grumbles home to a groggy sleep.

If Charley is the thirteenth boy—and thank God the last—and parental eyes see him bubbling over with unexplainable mentality and are sure that his only rightful destination is college, and that he should go without financial worry, then a portion of the preceding dozen must stay at home and sweat for Charley's sustenance while the culture factory does its worst. No one receives direct benefit except Charley.

When unaided human effort is all that we live by, a full day for every one is the penalty for bare existence. This holds true, even in the kindly tropics if one would keep snakes out of his bed and tarantulas out of his soup. Without machines, if one man defaults, another must pay; but with machines one man or many men may default and it is the machine which pays. Who cares if the machine suffers with sweating and groaning and working overtime as long

as it has sufficient oil on its moving parts?

Critics of this and that will never lack material. No matter to what heights the mass intellectual nature may climb, those who profess to know will always pronounce the culture "terrible." The classicists will mumble across the stage and preach of the bygone days when real men were bootleggers and art was art; perhaps calling up the shades of Paul Whiteman, Harrison Fisher and Zane Grey. The tumble bugs will tumble; time will pass on, going out from under those who study its events. Historians now forget the terrible stench which must have been the populace of the Age of Pericles and fail to give economic conditions due credit for what was done. Since the Cro-Magnon man first grunted self-admiration for a reindeer scratched on a wall it is very doubtful if the variations in the mass average of individual abilities from place to place and time to time have been at all commensurate with variations of means and opportunities for action. If art is lacking to-day look for the change of social history rather than the lack of artists and their works. The author has the shameful feeling that the requisite initiation into the arts to enable one to judge is never complete until a certain large quantity of prejudice has been instilled. There is little question but that it takes more than the naturally endowed five senses to see beauty in an old master.

A great many things of at least temporary beauty and worth will always be produced, probably in even greater quantities than now, because fewer artists will be digging in mines or milking cows. As to the greatness of the works—well, that depends too much upon the fads of group intellect, which depend upon the accumulated internal secretions of many generations past—we see no hope of remedy.

To those who stop and judge, most of the people will be low-brows. They will know much more and possibly be more genteel than the corresponding group to-day, but still low-brows. Individual differences will bob up again and again at the most inopportune moments. If any high-brow expects the low-brows ever to become cultured he awaits only disappointment, it makes no particular difference what age he chooses to live in, because relativity is a potent principle in biology as well as in physics. If there are any ultimate standards, presumably the culture will improve, but it is hard to say what these ultimate standards will be unless they mean washing the teeth more often and being unwilling to consider the weather a fit topic for conversation.

Our cultural future rests almost entirely with our educational system. Leisure and education are the Siamese twins of the future social sciences. As the potentialities of the machine and of industrialism rise to their destined places the present tendency of education for the trade will be of minor importance and education for leisure will come to the fore, just as it has always done in the past in schools for the privileged classes.

There can be little doubt that in the future our leisure is to be of much greater importance than now. The above estimate of two hours a day for work may be wrong, but whatever the number of hours required to fill the world's needs it is quite certain that when the allotted task is finished the day will only be well begun and human energy, *en masse,* must have some place to go.

Even before the age of leisure for all has been established the educational machinery will have to get busy with new thoughts. The musty old argument reputed to have been a favorite of the late Judge Gary, "What will they do with their time if they don't work twelve hours a day?" becomes really

significant and important if the number of hours is reduced to five or six. If 99 per cent. of the people were of the variety who just sit and think and then part of the time just sit, the educational problem would be very simple—it does not take long to master the technique of sitting.

The first question of human existence is, "When do we eat?" The second in importance appears to be that of sexual gratification. After these two items are cared for, and sometimes even before, the urgent question becomes, "What shall we do now?" Some people, particularly the obese, never get beyond first base; a great many more never get any farther than question two, but what of the others? What do they do? Some fish, play golf, read, write, hunt, paint, raise chickens—a multitude of things which hurt no one, not even the participant. Others become nosey about their neighbor's business—witness the Boston Watch and Ward Society; some find murder a very pleasant pastime; more go to great lengths for political or social power; others gain a great deal of satisfaction from imposing on the religiously credulous. There are sex perverts and snobs and scandal-mongers; there are an enormous number of ways of hampering human happiness, and some one always manages to think of all of them.

Viewed as a whole, modern American education emphasizes the ritual of the preparation for particular trades or professions. As we become more and more liberated from the shackles of the working day the emphasis must be shifted back to the more classic goal of preparation for idleness, or, to phrase it more genteelly, for leisure. This training for leisure must do two things: it must orient the person in his intellectual world, minute as it may be, so that he may gain the greatest possible happiness therefrom; and it must teach him to be willing and able to allow other people to enjoy their happiness in their own manner as long as it is not disastrously anti-social, amounting to a public nuisance.

It is hard to see how we can get along on less technical training than we have at present, so for the extra schooling on how to live there is but one answer—more time. The period for formal instruction must last for the average, let us say, until the age of twenty-five. Specialists will probably never be able to divorce themselves entirely from some educational institution.

Granted that the main object of this high degree of education for all is to be the acquisition of culture, of regard for others and possibly the development of a sense of humor, how is it to be done? I confess that I do not know. What will the curriculum be? That's just another verse of the same song, I do not know. It is possible that the departments of education, in spite of themselves, will have made some progress in the matter before the two-hour day gets here. Every generation which is somewhat educated will help by furnishing better home environment for those to come. The prospect is not entirely hopeless, but there is nothing to cheer about as yet. Undoubtedly, to reach every one or nearly every one a great deal of dishonesty and subterfuge will have to be employed and courses be given in "Ethics for Waiters and Mechanics" or "Culture for Chamber-maids"—the appeal must be made universal. God help the educators!

Any one will admit that there will always be many who are not susceptible to education and who are proud of it. It must be remembered, however, that education, like almost everything else, is purely relative and that a great deal can be forced into empty heads when public opinion makes the proper demands. It is to be hoped that the actual mental defectives will pass out of the picture, as they surely will as soon as social preju-

dices against sterilization and humane death for the hopeless have passed away.

Despite their shortened labors the average man and woman will have many more possessions than now. There is no use in talking about how much. If we argue about points on which we have no data the discussion becomes merely polemical. We venture to assert, however, that it will be a very unsatisfactory world until any man of average ability can, during the course of a reasonable life, become fittingly educated, fulfil his labor obligation to society, have all the possible mechanistic devices at his disposal either by ownership, rental or paid admission and then have sufficient time and means to ransack every portion of this sphere if he chooses, and then, finally, if death really proves inevitable, may it be slow in attacking and painless in its action.

The barriers between the races of the present must surely dissolve under the action of the solute of trade. We will associate too freely and become too intimate for the present great differences to be maintained. As to what race will survive and what shade or color the future citizen will acquire we do not know. Probably it will be an intermediate complexion, usable in the tropics or the Arctic, for the average person will be a very mobile individual and will move from one end of the earth to the other on a day's notice. That particular brand of mental raw meat sponsored by Kipling, Stoddard and Company and pawned off as "The Burden of Civilization of the White Race" (particularly Anglo-Saxon) will eventually be discovered to be thoroughly putrefactive and will be properly incinerated in the ovens of public opinion, and the consolidation of the races will begin where the gaps are small. We of the future will miss the great varieties of people, but that will be one of the inevitable burdens we must bear. Possibly we can develop new animals to satisfy people's curiosity.

Naturally there will be but one language, but one government and but one set of laws upon the earth. The mechanical equipment for such solidarity is already more than sufficient. If all of us, the entire billion and a half, should suddenly be shaken up and cast forth by some supreme landlord and should go pioneering to another planet of about this size, taking all our means of communication and travel, it is inconceivable that we should come out of the shuffle with more than one government or more than one language. It is only the stupendous social laziness ("inertia" is a less irritating word) of Mr. John Doe which keeps such a social adjustment from happening next week.

It is hardly necessary to state that all these predictions are placed on the basis of the absence of war. The two-hour day certainly can never be reached as long as there are those who get out of control periodically and set out to put civilization's progress back a thousand years in a few short days or months.

The ultimate industrialism can never be thought about or even dreamed of until the world as a whole can rest on the assurance that war is an impossibility. The view of some that war can never be eliminated because of certain innate characteristics of human nature is, at its best, a sort of a bloody rationalization to uphold certain prejudices. Economic factors are probably the major causes of wars in the present era, and thus probably will be the principal contributor to the stoppage. When all the merchants and tradesmen of all dimensions who might possibly be involved in a war become thoroughly convinced that there is no possibility of either side being an ultimate winner, then vigorous steps will be taken very quickly to settle differences by allowing twelve select

business men to see which one can pound a table the longest and the hardest, rather than having twelve million of the populace make sausage of each other for the sake of some myth of national honor or a catchy phrase.

It would seem that nothing has made people so perpetually susceptible to war hysteria as orthodox religion. Certainly no unbiased observer is able to discover a difference between the mass methods of getting volunteers for Jesus and volunteers to fight the Hun. Passing conscription acts does not eliminate the necessity for volunteers. It would be very interesting to see any commander-in-chief round up a whole country full of conscripts if they all had a very definite idea that they were not going to be thus seduced. To one on the outside it appears that orthodoxies are dying a more or less lingering death. Man as a whole is progressively becoming convinced that this life is all and that all things beyond are so shadowy they should be discounted 100 per cent. Unconsciously, he begins to think more of the sweetness of life and less of national honor.

The battle between science and religion (in the present sense of the word) is inevitable and real. No quarter can be expected from either side. Creeds and supernaturalism are inimical to a scientific point of view of life. All the dangerous possibilities of the industrial age of the future can be controlled only if the social history is built on a foundation of humanistic but materialistic rationalism.

With supernaturalism ruled out it is hard to see how a religion will survive. On the other hand, it seems psychologically impossible for all the populace to cast off the cloak. How much of this is inherent and how much a product of social history no one could dare to say. Probably there will be some sort of a religion in the future, but certainly one that does not confine itself to the shores of Galilee or to Mecca or the Ganges. What its central theme will be is interesting to guess. As to subject-matter, it may be expected to be a sort of generalized course of ethics—an elongated Unitarianism.

Along with all these sociological problems and attracting much less attention are the purely biological ones. Let us assume that the ultimate physiological aim is the longest possible life with a minimum of pain and discomfort. What may we expect? Although practically nothing has been done to extend the upper limit of expectant life, it is not unreasonable to suppose that eventually disease will practically be eliminated, the hazard of accidental death greatly reduced and that our insurance rates will take a sharp drop. If you leave man in a perfectly healthy state for a century, the ensemble seems to wear out; the slender connecting links between the living cells snap and life is done. The problem of extending the phenomena is yet too great. Biologists are usually pessimists on the subject, but so are all specialists; some day the mechanistic secrets of life will be discovered and then it may be that the collective life of the cells of a man may be extended on and on. Then, and not till then, will man be master of his soul, if he still wants to use that word.

After a man has had life prolonged and lived to a really venerable age he may have time to accomplish many of the things he would like to accomplish instead of only the few which are his allotment for the present period of activity. Even then he can never waste time looking for a purpose where probably there is none. Let it pass. Human happiness is the only reality. Do nothing to lessen it.

ALLIGATORS OF THE OKEFINOKEE

By Dr. FRANCIS HARPER

SWARTHMORE, PENNSYLVANIA

AFTER my earliest trip to Georgia's great swamp, a naturalist friend laughingly inquired whether I had seen any alligators there in the act of catching mosquitoes. He went on to explain that such a scene had been depicted in one of the school readers or geographies of his boyhood days. In this way the name Okefinokee had become impressed upon his memory, although, in common with most naturalists and the public at large, he had remained in practically total ignorance of the real nature of this enchanting wilderness up to a score or so of years ago. Nowadays it is a little difficult to recall what a *terra incognita,* what a place of mystery and legend, the Okefinokee was so short a time ago.

The image of the entomophagous alligator had all but faded from my mind when it was strikingly recalled last summer by Lone Thrift, an elderly hunter of the region. We were idling one noon by the side of Suwannee Lake, when he astounded me by telling with circumstantial detail, out of his own experience, how this animal opens its mouth, while resting upon a log or a "battery," until its tongue becomes covered with mosquitoes, whereupon it brings its jaws together with a resounding smack and so makes an end, if not a meal, of the buzzing pests.

Scoff at the tale? Far from it. Long association with the men of the Okefinokee engenders faith in their words, and in the present case that faith has been growing steadily. A basking alligator doubtless has as much reason to open its mouth as a basking crocodile, and I have even seen the tongue and teeth revealed plainly between the wide-apart jaws of one swimming quietly along. The presence of leeches or other parasitic worms might be worth investigating as a primary cause of the habit among crocodilians of basking with open mouth, for such parasites would very likely be affected unfavorably by direct exposure to strong sunlight. And what would be more natural than a mosquito's seeking to draw blood from the tongue? Certainly no sane *Culex* or *Anopheles* would attempt to penetrate any part of the animal's external armor. As for the liability of "coldbloods" in general to mosquito attack, I have seen two of these pests attached for minutes to a green frog's legs.

In this connection it is of surpassing interest to note that Geoffroy Saint-Hilaire[1] observed gnats infesting the mouths of crocodiles on the Nile and that he quoted from Dr. Descourtilz a like report concerning *Crocodilus acutus* of Santo Domingo. It is still more thrilling to find what True says:[2]

> It would appear that they [alligators] are also expert fly-catchers. The quaint allusion of Exquemelin ["Buccaneers of America," English translation, p. 48, 1684] to this subject is too interesting to be omitted. "The *Caymanes,*" he says, "are ordinarily busied in hunting and catching of flies, which they eagerly devour. The occasion is, because close unto their skin, they have certain little scales, which smell with a sweet scent, something like unto musk. This aromatick odour is coveted by the flies, and here they come to repose themselves and sting. Thus they both persecute each other continually, with an incredible hatred, and antipathy."

[1] E. Geoffroy Saint-Hilaire, "Mémoire sur deux espèces d'animaux nommés *Trochilus* et *Bdella* par Hérodote, leur guerre, et la part qu'y prend le Crocodile," *Mém. Mus. Hist. Nat. Paris,* 15: 459–474, 1827.

[2] F. W. True, "The Fisheries and Fishery Industries of the United States." Part 2. "The Useful Aquatic Reptiles and Batrachians of the United States," pp. 137–162, Washington, 1884.

> The existence of this habit, I have recently been informed, has been frequently confirmed in Louisiana by reliable observers; but the gentleman who informed me was inclined to believe that it is the saliva which attracts the flies into the gaping jaws of the Alligator.[3]

The venerableness, the persistence and the independent origin of the reports on such a habit surely entitle them to respectful consideration.

It was long the fashion to laugh at Herodotus for his account of a bird that enters the gaping mouth of the crocodile in order to pick off the leeches that it finds there. Yet modern observations have gone far toward substantiating this "traveler's tale," and have even identified the bird as the black-backed courser (*Pluvianus aegyptius*). And who can say that the mosquito-destroying alligator may not eventually find its scientific eye-witness and champion?

The bellowing of the alligator and the actions accompanying it are so remarkable that some accounts of the performance have been looked upon with considerable skepticism, especially perhaps by those who have not been in the animal's haunts. In the celebrated "Travels" of William Bartram[4] we may read: "The earth trembles with his thunder. . . . The shores and forests resound his dreadful roar." In similar vein, Audubon[5] wrote of large numbers "groaning and uttering their bellowing noise, like thousands of irritated bulls about to meet in fight."[6] Any one inclined to doubt Bartram's or Audubon's accuracy should have been with me on the Big Water one May evening in 1912 and shared one of my first experiences with this appalling sound. I was camping with one of the Billy's Island boys on a little platform of logs barely raised above the dark waters of a gloomy cypress bay. Suddenly, and from near by, a bass roar broke upon us, of such awful volume that the whole atmosphere was charged with it and the very cypresses about us seemed to vibrate with the sound waves. Every few moments the roar was repeated. Any one hearing such a tremendous bellow close at hand in the darkness, and unaware of its source, could scarcely fail to be struck with terror.

The bellowing may be heard at intervals throughout the warmer months of the year. I have heard it oftenest during the middle or latter part of the morning in May, June, August and September. On a September morning one or two distant gators commenced bellowing on Grand Prairie, and presently half a dozen responded from various directions. Each bass, muffled roll lasted about two seconds, sounding loudest at the start and dying away at the end. The volume of sound must depend largely upon the size of the individual, for occasionally a bellow heard even near by may make no extraordinary impression of loudness. At times a peculiar humming quality may be discerned in the bellowing. One day last June, on Floyd's Island, I looked involuntarily for a humming-bird about my ears before I realized that I was listening to the great bull-like, humming roars of three or four gators somewhere out in the swamp. A swamp hunter will tell you that the sound carries as far as two miles on a still morning.

No other living reptile is known to produce such a volume of sound. If any *Brontosaurus* or *Diplodocus* of Mesozoic times ever filled the air with vocal thunders, here, probably, is the nearest counterpart of such sounds in the world of to-day. To the paleontologist who would relive the dim past, who would

3 P. 142.

4 William Bartram, "Travels through North & South Carolina, Georgia, East & West Florida . . ." pp. xxxiv + 522, 7 pl., Philadelphia, 1791.

5 J. J. Audubon, "Observations on the Natural History of the Alligator," *Edinburgh New Philos. Jour.*, 2: 270–280, 1827.

6 P. 271.

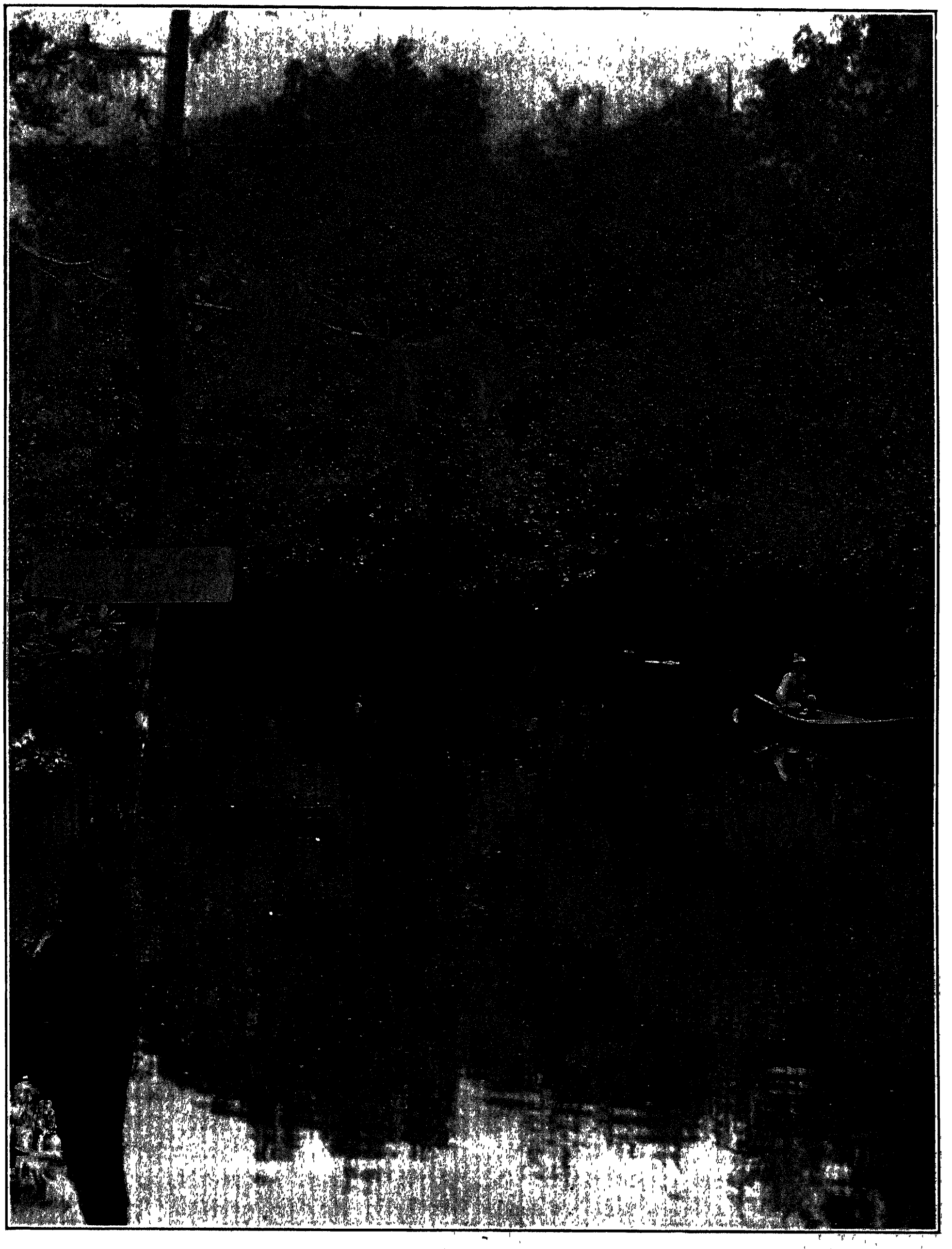

FIG. 1. SUWANNEE LAKE,
WHERE ALLIGATORS ARE THOROUGHLY PROTECTED. TWO MAY BE SEEN NEAR THE FARTHER SHORE.
JUNE 28, 1929.

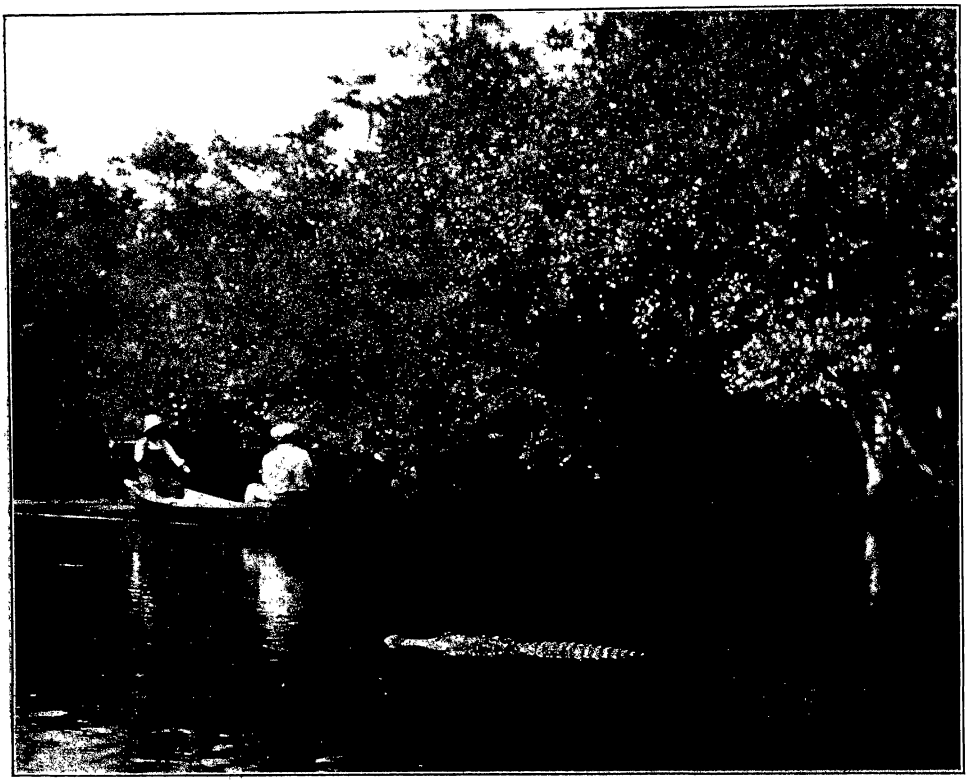

FIG. 2. THE ALLIGATORS OF SUWANNEE LAKE
OFTEN SWIM FEARLESSLY WITHIN FIFTEEN OR TWENTY FEET OF A BOAT. JUNE 28, 1929.

see in his mind's eye a host of prehistoric monsters wandering over some Jurassic morass, I commend a sojourn in the vastness of the Okefinokee. How could the mood for such fancies be better induced than by giving ear to the alligator's savage music, as it rolls over these watery solitudes, resounding from prairie head to cypress bay?

Under ordinary circumstances the alligator of the present day remains rather shy and aloof, and could hardly be expected to indulge in its vocal performance within view of a human observer. Few of the swamp hunters seem able to give any adequate account of it, and I myself scarcely had a thought of ever having the good fortune to witness it. Last June, however, an exceptional opportunity occurred while I was spending some days at Suwannee Lake (Fig. 1), a few miles from the western border of the swamp. The owner of the lake, Mr. Hamp Mizell, rigorously protects the gators that frequent it, to the number of half a dozen or so. Consequently the big reptiles will often swim fearlessly within fifteen or twenty feet of a boat (Fig. 2). One morning a nine-footer commenced bellowing as it swam slowly across the lake, with its head pointed out of the water at an angle of about 30 or 40 degrees (Fig. 3). With its head in this position, its back was necessarily submerged, but a terminal portion of its tail projected almost completely above the surface. This portion appeared to be a couple of feet long, and

was strongly arched, so that the extreme tip bent downward and dragged in the water, as the tail, functioning as a propeller, waved slowly from side to side. As each bellow sounded from its open mouth, the creature's throat swelled like a bullfrog's. There is doubtless a special advantage in the upward tilting of the head at this time, in that it permits the free escape into the air of the musk emitted from glands in the lower jaw. Each bellow lasted for perhaps a second, and as it concluded, the head sank down in the water till it was almost or quite submerged. In two or three more seconds the head was raised again and the bellow was repeated. On this occasion the gator ceased after a very few repetitions. In the meantime another gator not far away gave some answering bellows. Very often, it appears, the bellowing of one of these animals will call forth a response from others in the vicinity.

One may judge of the rarity of observations on the bellowing of the alligator from the fact that no detailed eye-witness account of the performance will be found in the standard works on reptilians or even in Professor Reese's well-known monograph of the species.[7] Many, of course, have heard the bellowing without the faintest chance of observing its authors in the act. The only genuine, first-hand account by a naturalist that I have discovered is that of the learned William Bartram, in his "Travels through North & South Carolina, Georgia, East & West Florida." This classic could not be overlooked by any zoologist, and the all but universal failure to quote his description of the bellowing must be ascribed to an unfortunate evaluation of it as too fantastic or exaggerated to be worthy of credence.

[7] A. M. Reese, "The Alligator and Its Allies," pp. xi + 358, 28 pl., 62 fig., New York and London, 1915.

Clarke[8] does venture to quote it, though he considers it "written with such spirit and enthusiasm as to carry the author beyond the limits of simple and accurate statement."[9] "Most evident hyperbole!"[10] and "obvious embellishments"[11] are some of the judgments pronounced.

Now suppose we examine the very words in which Bartram describes what he saw on the St. Johns River, Florida, in the early summer of 1774:

> Behold him rushing forth from the flags and reeds. His enormous body swells. His plaited tail brandished high, floats upon the lake. The waters like a cataract descend from his opening jaws. Clouds of smoke issue from his dilated nostrils.[12]

Again he speaks of

> the incredible loud and terrifying roar, which they are capable of making, especially in the spring season, their breeding time. It most resembles very heavy distant thunder, not only shaking the air and waters, but causing the earth to tremble. . . . He now swells himself by drawing in wind and water through his mouth, which causes a loud sonorous rattling in the throat for near a minute, but it is immediately forced out again through his mouth and

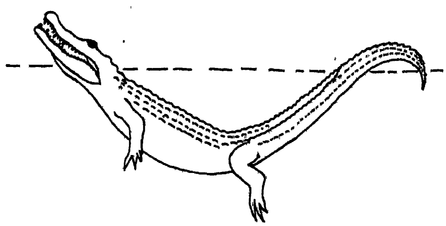

FIG. 3. ALLIGATOR IN THE POSITION OF BELLOWING
(EXACT DISPOSITION OF LEGS PROBLEMATICAL.)

[8] S. F. Clarke, "The Habits and Embryology of the American Alligator," *Jour. Morphology*, 5: 181–214, 5 pl., 1891.

[9] P. 184.

[10] True, *op. cit.*, p. 145.

[11] Remington Kellogg, "The Habits and Economic Importance of Alligators," Tech. Bull. No. 47, U. S. Dept. Agric., December, 1929, pp. 1–36, 2 pl., 2 fig. See page 10 for quotation.

[12] Bartram, *op. cit.*, p. 118.

FIG. 4. GRUNTING FOR AN ALLIGATOR
IN A CYPRESS POND ON BILLY'S ISLAND. THE POLE IS HELD WITH ONE END AT THE HUNTER'S MOUTH, THE OTHER IN THE WATER. MAY 10, 1912.

nostrils, with a loud noise, brandishing his tail in the air, and the vapour ascending from his nostrils like smoke.[13]

The fidelity and accuracy of Bartram's account as a whole, with only the slightest indulgence in poetic license, are most impressive. In my limited observation I did not verify every detail quoted above, but Bartram's opportunities were vastly superior to mine. At the time of his trip on the St. Johns, alligators were amazingly abundant and ferocious, and made determined attacks upon him, from which he escaped only by the most desperate resistance. In their own concerns they were so indifferent to his presence that he was able to make his observations repeatedly, and at such close range as would be inconceivable at the present day. Only three or four essential details in his account remain to be verified or rejected: "the vapour ascending from his nostrils," "drawing in wind and water through his mouth" and the duration of the "rattling in the throat for near a minute." The "ascending vapour" was very probably seen by Bartram, though more likely to have come from the musk glands on the lower jaw than from the nostrils. While not exactly "drawn in," water might easily enter the mouth as the head sinks down toward the end of the bellowing. The air is probably inhaled through the nostrils rather than through the mouth. As for the rattling lasting "for near a minute," Bartram may have meant to refer only to the length of time during which the series of sepa-

[13] Pp. 129–30.

rate bellows continued, and not to one continuous rattling. In any event, we may here acknowledge our indebtedness to one who was no heedless romanticist, but a scholar who has preserved for us a priceless record of certain phases of American nature that have passed forever.

The actual mechanism involved in the emission of the musk does not seem to have been investigated. It may be produced by some muscular tension that is simultaneous with the vibration of bellowing if not directly connected with it. Though true vocal cords are said to be wanting, the laryngeal cavity is so constructed that the bellowing is evidently produced by the passage through it of air forcibly expelled from the lungs. The sinking of the head at the conclusion of the bellow may be ascribed to the increase in the animal's specific gravity as the lungs are deflated. Conversely, the refilling of the lungs, with the accompanying decrease in specific gravity, must enable it to raise its head well out of the water into the position for bellowing. A frog's alternate inflation and deflation of its lungs in croaking correspond to the alligator's action.

When the swamp hunters wish to lure a submerged gator to the surface, they utter a peculiar whining grunt, with a rising inflection, from deep in their chests: *unhh!, unhh!* This is so effective that they maintain it will bring one up even after it has been shot at. They will commonly grunt for a gator simply for the fun of seeing it emerge. The young ones are said to have such a note of their own, and it may be out of some concern or interest in them that the adult on hearing the grunt rises to the surface to look about. In order that the sound may carry better beneath the surface, the hunter will rest one end of his push-pole in the water and bring the other to his mouth (Fig. 4). The sound waves are supposed to be transmitted more effectively along the pole than through the atmosphere into the water.

One of the Billy's Island boys used to amuse himself by calling out in a deep voice to any gator at the surface, "Hey, *Jim!*" His object was to cause the creature to submerge, and he generally seemed to gain his end almost immediately. One day, when the two of us paddled around a sharp bend in the St. Marys River, we found ourselves almost alongside the hugest gator we had ever encountered. As it rested there on a sand bank, its girth appeared like that of a turpentine barrel, and we judged its length was very close to fourteen feet. Very deliberately and without fear it eased off the bank into the river and took a course downstream. The sudden apparition of the monstrous reptile at such close quarters had shaken my companion's nerves a bit, and so he was not long in singing out "Hey, *Jim!*" with the effect he desired.

During those countless years in which the Seminoles and other Indians, with merely their bows and spears, held sway over the Okefinokee, the alligators must have been extremely abundant. In the early days of the white settlement (about the time of the Civil War), the great reptiles were said to have been so numerous on Billy's Lake as to make it appear that one could "walk across the lake on gator backs." In remote parts of the swamp they remained extraordinarily plentiful and bold to a much later date. For example, Allen Chesser used to tell of witnessing a great concourse of gators, to the number of possibly three hundred, making a drive for fish in Buzzard Roost Lake. This happened about 1890. Even twenty-five years later he and a companion killed fifty-eight gators in this same small lake in a single night.

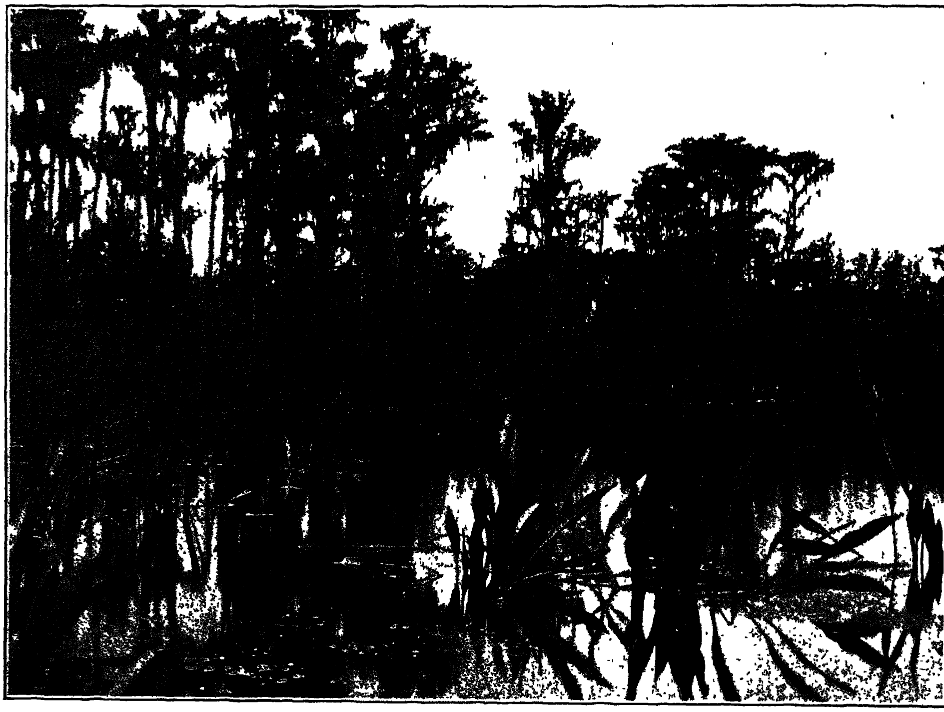

FIG. 5. A GATOR-HOLE
ON FLOYD'S ISLAND PRAIRIE. JUNE 18, 1929.

At the time of publishing Allen Chesser's tale,[14] I had quite forgotten the spirited picture which Bartram has left of a remarkably similar incident of 1774:

The river . . . from shore to shore, and perhaps near half a mile above and below me, appeared to be one solid bank of fish . . . pushing through this narrow pass of St. Juans into the little lake . . . and . . . the alligators were in such incredible numbers, and so close together from shore to shore, that it would have been easy to have walked across on their heads, had the animals been harmless. . . . Whilst this mighty army of fish were forcing the pass . . . thousands, I may say hundreds of thousands of them were caught and swallowed by the devouring alligators. . . . The horrid noise of their closing jaws, their plunging amidst the broken ranks of fish, and rising with their prey some feet upright above the water, the floods of water and blood rushing out of their mouths, and the clouds of vapour issuing from their wide nostrils, were truly frightful.[15]

Audubon has described from Louisiana a somewhat similar scene:

When alligators are fishing, the flapping of their tails about the water may be heard at half a mile. . . . The alligators thrash them and devour them [the fishes] . . . while the ibis destroys all that make towards the shore. . . . You plainly see the tails of the alligators moving to and fro, splashing, and now and then, when missing a fish, throwing it up in the air.[16]

Bartram's, Audubon's and Allen Chesser's accounts support one another by their similarity, though more than a century had elapsed between the first

[14] Francis Harper, "Tales of the Okefinokee," *Am. Speech,* 1: 407–420, 1926. Account of alligators on pages 417–418.

[15] Bartram, *op. cit.,* p. 123.

[16] Audubon, *op. cit.,* pp. 273–275.

and the last. All three refer to the alligators thrusting their heads out of the water after seizing or attempting to seize a fish. Two of the three mention the presence of herons and ibises, which picked up fishes forced to the shore. None of the descriptions is more graphic or detailed than Allen Chesser's.

In the early days of their abundance, before they had become well acquainted with firearms, the alligators were much more generally aggressive than nowadays. In those days, I have been told, it was customary for the swamp hunter to carry an iron-shod pole in his boat for use in warding off their attacks. At the present time the vast majority of them are so inoffensive that the men and boys of the Okefinokee seldom hesitate to swim in alligator-infested waters. Though I can not vouch for their authenticity, tales are still told of an intrepid boy, Henry Saunders, who used to dive for alligators right into their caves on Suwannoochee Creek, near Fargo. After securing a hold with his hands, he would give a few kicks as a signal for his mates to haul him out by his feet. There was also an alleged crocodile in this creek which would always catch the sticks thrown at it by the boys. Henry would climb up on something like an overhanging tree, drop on to the crocodile and cause it to sink. But finally he dove into one too many caves; an alligator terrapin bit his thumb during one of these pranks, and thereafter he desisted from his sport.

Occasionally, to this day, an Okefinokee gator will make a more or less determined attack upon a person or a boat, but I have never heard of such an encounter resulting seriously. One day in January, 1917, a seven-footer made for David Lee near Dinner Pond Lake. At first he endeavored to get out of its way, but finally had to shoot it. Jackson Lee tells of a larger gator that, without provocation, bit a piece out of the side of his boat and broke his paddle in two before he could subdue it with rifle and shotgun.[17] Hamp Mizell's single experience of this sort was once when he stepped ashore from a boat in the canal, and a gator went up the bank after him. Possibly it was one of two gators that had been fighting near by. The swamp hunter commonly takes a dog with him in his boat, and in most cases it may be the dog, rather than the man, that tempts the gator to attack.

At times a gator will exhibit a strange indifference or unwariness toward a human being. Once a four-footer, basking on a log in Billy's Lake, allowed me to paddle almost within a boat's length before it slipped into the water. Last summer I was paddling quietly along the canal, trying to investigate a noise in the bushes on shore, when suddenly I noticed a six-foot gator within a couple of yards of me. It was resting motionless with its head partly out of the water and with the front portion of its body visible beneath the surface. I could have easily touched it with the paddle. While I was considering ways and means of securing a photograph, it quietly drew back out of sight. Years before I had come upon a similarly unwary gator in the canal. It is just possible that these individuals had become sluggish from wounds.

On land this essentially aquatic reptile is at somewhat of a disadvantage. Its great body, raised slightly off the ground by its legs, but with the tail dragging, is generally thrust along at a slow crawl. Its efforts to reach its more natural element from the land are sometimes clumsy and violent. In paddling along the canal, one is often startled by a terrific lunge and splash as a big gator hastily deserts the bank for safety in the

[17] *Am. Speech*, 1: 419, 1926.

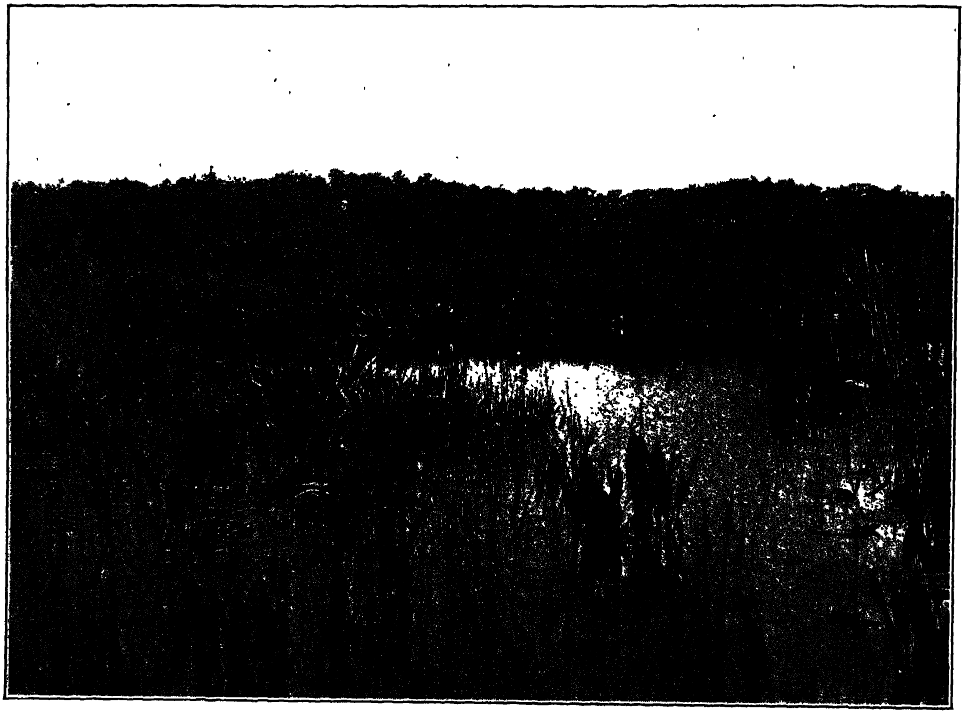

FIG. 6. A GATOR-HOLE
ON CHASE PRAIRIE, ABOUT FORTY FEET IN DIAMETER. JUNE 20, 1929.

water. Once as I was poling across a gator-hole on Grand Prairie, its denizen, resting on a "battery" behind a screen of water plants, first made its presence known by throwing a monstrous tail a yard in the air as it scrambled and splashed into the water. When unconcerned, the alligator swims along with much of its back as well as the upper part of its head above the surface. When it makes a speed of as much as three miles per hour in this fashion, it is going faster than usual. In the presence of danger it will show only its head, and less and less of that as the danger becomes more imminent. Finally, with a swirl of its tail, it submerges altogether. Its course may still be followed by the air that is exhaled now and then and rises to the surface in the form of bubbles. In local parlance these are always known as "blubbers." The gator-hunter keeps a sharp lookout for the blubbers, for they often enable him to locate an unseen animal and to prod it out from its cave or other hiding-place.

The alligator is at home on all the watercourses of the Okefinokee, including lakes, "runs," prairies, gator-holes and cypress ponds. Some of the lakes, such as Billy's and Minne's, are long and narrow, and are walled in on both sides by dense cypress bays. Others, such as Buzzard Roost and Gannet, have a broader expanse and lie in the open prairies. The Okefinokee "prairies" are really marshes, with enough water on them, in most places, to float a boat. The gator-holes (Figs. 5 and 6) are miniature lakes in the prairies and elsewhere, varying from perhaps one to ten rods in diameter and generally not more

than four or five feet deep. The animals themselves probably play some part, whether deliberately or unconsciously, in keeping the gator-holes clear of the encroaching vegetation. Generally two or more gator-roads lead from each gator-hole out into the surrounding prairie or to another gator-hole. They are passages or channels through the marshy vegetation, averaging two or three feet wide and a foot or two deep, and are obviously kept open by the animals passing through them. The Okefinokee hunter also is glad to make use of the gator-roads in poling his small boat across the prairies. Somewhere at the bottom or side of the gator-hole is the animal's "cave," where it takes refuge at a time of danger and where it probably spends the period of hibernation. Where the gator-hole adjoins a prairie "head" (a wooded islet), the cave may be located beneath an overhanging bank at the border of the head. The smaller gator-holes may harbor a single animal, and the larger ones, several. Probably each occupant exercises some sort of proprietary rights over its home territory and does not ordinarily wander far away.

In the region surrounding the Okefinokee the alligator frequents the rivers, creeks and branches, and also many of the cypress ponds that one finds here and there throughout the pine barrens. I have observed it in the salt or brackish marshes of the St. Marys estuary within eight miles of the open sea.

During a few of the colder months the animals disappear for the most part, being evidently in a more or less complete state of hibernation in their caves or other places at the bottom of the watercourses. At this time of the year the otters wander more frequently over the prairies than during the summer, apparently taking advantage of the inactivity of their voracious neighbors. Occasionally, however, an alligator will make its appearance right in midwinter.

The staple food of the alligator in this region is probably fish, with the addition of such other aquatic animals as it is able to capture. A wide variety of these animals is available in the swamp, including crawfish, frogs, salamanders, snakes, turtles, ducks, grebes, rails, gallinules, rice rats, water-rats, otters, raccoons and hogs. A drive for fish, the unsuccessful pursuit of a moccasin and the seizure of a mallard are among the observations reported by local hunters. Not the least interesting item in the gator's fare is an occasional member of its own species! For example, Sam Chesser once told me of lying in wait for one of the animals at a gator-hole, and of presently seeing it rise to the surface with a smaller gator in its mouth. He even heard the hide and bones crack as the cannibal devoured its prey. When Jackson Lee cut open an eleven-footer he had killed in Big Bonnet Lake, he found that it had eaten one of its fellows. The tail of the victim was whole and measured a little upwards of three feet in length. The same hunter also told of a trick that must be very useful to a gator in seizing and subduing some of its larger victims, though he himself had never seen it practiced on anything but sticks.

"You let a gator ketch a-hold er somethin' he cain't manage very well, an' he'll roll over an' over. You give 'im a stick when 'e's mad, an' he'll turn over an' over with it."

However powerful the jaws may be in closing upon an object, the muscles that open them are strangely weak. I have seen a five-foot animal with its jaws tied together by a mere bit of cord. I have also seen a hunter take a wounded gator and hold its jaws shut with his bare hands.

FIG. 7. SETTING OUT ON AN ALLIGATOR-HUNT
NOTE THE BULL'S-EYE LANTERN STRAPPED TO ONE HUNTER'S HEAD. MAY 9, 1912.

An experienced gator-hunter informed me that he had heard all his life the old story to the effect that gators will "get 'em a mess er pine knots in winter," but that he himself had never found any evidence of the habit. It may be that he had not had sufficient interest to investigate the contents of many stomachs, for there are numerous authentic records of stones and pieces of wood in the stomachs of alligators and crocodiles. Audubon,[18] for example, said on this subject: "I have regularly found round masses of a hard substance, resembling petrified wood." Catesby[19] spoke of "chumps of *Lightwood* [fat pine], and pieces of Pine Tree Coal, some of which weighed eight Pounds."[20] A young hunter of Billy's Island told me of finding three "cypress knots" in the "maw" of a gator he had cut up. They were about the size of one's fist, and "were wore plumb slick." Later a friend at Mixon's Ferry showed me a smooth-worn ball of dark wood, two or three inches in diameter, that had come from a 'gator's stomach. However the animals may come to swallow chunks of wood and retain them until they are worn smooth and round, these objects may serve somewhat the same function as the pebbles swallowed by geese and fowls; *i.e.*, they may help to grind up large pieces of food in the stomach. Since rocks and pebbles are practically non-existent in the Okefinokee, chunks

18 P. 280.

19 Mark Catesby, "The Natural History of Carolina, Florida and the Bahama Islands . . . ," vol. 2, pp. ii + 100, 100 pl.; appendix, pp. 1–21, 20 pl., London, 1731.

20 P. 63.

of wood are no doubt the best available substitute.

Little seems to be known of the alligator's courtship. Its bellow, like the voices of male frogs and toads, may well serve as a mating call, but this can hardly be its sole purpose, for it is heard long beyond the mating season. In the Okefinokee region mating ("just like a lizard") has been observed to take place in June, in the water. Probably some of the fights that are reported among the animals are encounters of rival males.

The freshly made nest may be found in early July. In size, shape and materials it resembles nothing else so much as a muskrat's house. One that I examined was about six feet in diameter and extended about two and a half feet above the water. The prairie vegetation had been stripped from a surrounding area about twenty feet in diameter to furnish material for the nest. There were thirty-two hard-shelled, elliptical eggs, occupying a space about a foot beneath the top of the nest. This was close to the average number, the complements of individuals varying from twenty to forty or more. This nest was situated close to a gator-hole in the prairie, where its owner, if so minded, could have kept a watchful eye on possible four-footed marauders. Nothing, however, seemed to have prevented numbers of turtles from taking advantage of the alligator's labors and depositing their complements of eggs in the soggy nest material. The eggs of this alligator were either hatching or ready to hatch by the end of August, after an incubation period of perhaps two months or thereabouts.

In spite of somewhat conflicting accounts, it is evident that the young ones do receive care from the mother. Bartram[21] saw "a young brood of alligators, to the number of one hundred or more [!], following after her in a long train" as she "passed close by the side of my boat." He "had frequent opportunities of seeing the female alligator leading about the shores her train of young ones . . . ; and she is equally assiduous and courageous in defending the young . . . and providing for their subsistence; and when she is basking upon the warm banks, with her brood around her, you may hear the young ones continually whining and barking like young puppies." Audubon[22] says, "The female leads them to the lake" as soon as hatched. Hamp Mizell's account[23] of conditions in the Okefinokee agrees well with the others:

> As soon as they are hatched the old alligator takes them in charge, grunting to them like a hog grunting to her pigs, and the young alligators keep up a continual squealing grunt, and by this method stay in a drove and under the protection of the mother. The young alligators leave their mother in about 4 months after hatching, and from then on they shift for themselves.[24]

The alligator-hunter (Figs. 7 and 8), sometimes alone but more usually with a partner, pursues his vocation from a boat during the hours of darkness. In past years he strapped an oil-burning bull's-eye lantern to his head for use in "shining" the eyes of his quarry; perhaps by this time he has substituted the more powerful electric flashlight. The skilful hunter generally manages to maneuver his boat so near that the muzzle of his gun almost reaches the gator's head. Certain details of this eerie pursuit were thus described by Walter Davis out of his ample experience:

> I gen'ly hunt by muhself. I have got as high as thirty er forty gators in a night. It takes anywhere frum fifteen ter forty minutes ter skin a big gator, dependin' how yer knife is an' how yer feel.

21 Pp. 126, 128.

22 P. 279.

23 Hamp Mizell in McQueen and Mizell, "History of Okefenokee Swamp," pp. 1–191, 27 pl., Clinton, S. C., 1926.

24 Pp. 50–51.

FIG. 8. HUNTERS WITH A SIX-FOOT ALLIGATOR
JUST TAKEN FROM A CYPRESS POND ON BILLY'S ISLAND. MAY 13, 1912.

Skinnin' gators is a matter er practice. When yer first start out, yer go slow; but the more yer kill, the more yer skin, an' the quicker yer go. Gator meat sure dulls a knife.

I use a little boat, sharp at both ends. Don't take the gators aboard, but leave 'em where they are. They sink when they're dead. First knock 'em in the head some if they're still a-movin'. When a feller's out till three er four o'clock in the mornin', he may sleep till this time er day [early afternoon], but if he has a lot ter skin, he may get up at ten o'clock in the mornin', an' cook 'im somep'n ter eat.[25]

The hunter has scarcely removed the hide before the buzzards gather for a feast. Where the carcass floats in the water and is thus unhandy to feed upon, the scavengers may continue at their noisome task for days. On land, however, nothing but a clean-picked skeleton is left after a few hours.

As a consequence of persistent hunting, the alligator population of the Okefinokee had probably dwindled, within the past five or ten years, to the lowest point it has ever reached. However, a recent turn for the better seems to have taken place. In my various trips to the swamp, which have covered a period of seventeen years, I doubt if I have ever found the animals so numerous as during the past summer. One afternoon, while paddling along the canal for half a dozen miles, a companion and I must have observed between fifteen and twenty individuals. This improved status of the species is chiefly due, I believe, to the attitude of the present owners of the swamp, who discourage the hunting of alligators in general and prohibit it entirely on Chase and Floyd's Island Prairies. At

[25] *Am. Speech*, 1: 418, 1926.

the same time many people have had a telling object lesson presented to them at Suwannee Lake, by observing how interesting and comparatively harmless a protected alligator may be.

The maximum size to which alligators grow is something of a moot question. Naturally the larger individuals are tougher to kill and probably also more difficult of approach; consequently it is perhaps only through some unusual chance that a rule is ever applied to one of the biggest fellows. The very formidability of these reptiles doubtless magnifies their size in the observer's eyes. Thus I am fairly ready to lop off a foot from the length of the apparent fourteen-footer that loomed before us on a sand bank of the St. Marys. One of the largest ever killed by Allen Chesser, during a lifetime spent in the Okefinokee, was just under ten feet; but he reported one of twelve and a half feet killed in the canal by Reese Rider and Giles Jacobs, and a thirteen-footer was said to have been taken by John Chesser. Samuel L. Davis spoke of catching one in the St. Marys that measured twelve feet and four inches. Hamp Mizell[26] refers to several "that measured from twelve to fourteen and a half feet long." A carcass being picked by black vultures on Floyd's Island Prairie last summer appeared to me between eleven and twelve feet long, but its condition did not invite an exact measurement. Bartram[27] says, "I have seen them twenty feet in length." Audubon[28] killed and measured one of seventeen feet. In former times the alligators had a far better chance for a long life, and doubtless attained a considerably greater size than nowadays.

Even when only the head of a gator appears above the surface, it is possible to make a fair estimate of its length, for the swamp hunters will tell you that there are as many feet in its total length as there are inches between the knobs that mark the position of eye and nostril; *i.e.,* a ratio of 12 to 1. And this ratio is nearly correct, at least for a large specimen.

The eyes of some alligators have a reddish reflection in the rays of a lantern or an electric flashlight, while those of others have a yellowish reflection. According to Hamp Mizell, the red-eyed individuals are the more vicious. It seems quite possible that the difference in color may be a secondary sexual character, as it is in the box turtle. It is well known that the males of this turtle have red eyes, while the females have yellow eyes.

One dark night, while sitting on the dock at Suwannee Lake with an electric flashlight in hand, I spotted about four different individuals by their glowing red eyes. The gleam was readily picked up at a distance of fifty yards. For the most part nothing of the gator was visible except those glowing orbs, now at rest, and now advancing without sound or haste through the gloom of the night. When viewed from the proper angle, both eyes were reflected in the water, making a constellation of four points. Eventually a five-footer was attracted by the flashlight to within a couple of yards of the dock. Even at that close range little more than its head was visible in the murky water, but what a cold, acquisitive, reptilian glitter in its eyes!

A few weeks previously Henry R. Carey and I had experimented with "jacking" gators on the old logging canal in the eastern part of the swamp. As we paddled silently in the black night along the eerie reaches of the canal, a great chorus of green tree-frogs sounded from the adjoining jungle, while now and then a southern toad contributed its droning roar. The dense shrubbery on either bank crowded into

26 P. 50.
27 P. 128.
28 P. 277.

the water, and some of the trees from opposite sides intermingled their branches overhead. In paddling downwind, we had brief glimpses of glowing eyes in several rather distant gators, but they did not suffer us to come near, and I wondered if they were suspicious of the odor of Carey's pipe. Various smaller lights, like diamond points, were discovered to be the eyes of water spiders. When, presently, we had turned and paddled against the breeze for a time, a mere eye was transformed almost too suddenly into a ten-foot monster, plated and corrugated, that moved past us, with easy sinuations of its body, almost within reach of a paddle. At that distance it surely looked formidable. In the fairly clear water of the canal we saw not only its projecting head but practically its whole length just beneath the surface. We had thus convinced ourselves of the feasibility of flashlight photographs from a boat, but the next night, when we made ready for a trial, a storm came up and thwarted our plans.

The relation of alligators to fishes and fishing in this region is something of a mystery and a paradox. Fishes must form a large, if not a major, part of their food. Yet the presence of alligators is so far from being detrimental to the fishes that it is actually looked upon with favor by the fishermen. Nowhere have I seen fresh-water fishing with hand lines to compare with that afforded in the alligator-infested waters of the Okefinokee region. Suwannee Lake, for example, with a length of barely a quarter of a mile in its main section and a maximum width of fifty yards, has a seemingly inexhaustible supply of warmouths, "stump-knockers," "thin-gizzards," trout, jackfish, red-finned pike, catfish and mudfish. During the season of 1925 alone the well-nigh unbelievable number of 41,618 fish were taken from this lake by hook and line. If the half dozen alligators that disport themselves there had any serious effect upon the fishing, they would hardly be protected as they are. As matters stand, they and the people who come in numbers daily to try their luck are mutually tolerant of each other. At the boat landing a sign is conspicuously posted: "Do not pest the alligators."

Some of the swamp residents will go so far as to claim that fishing is ruined by the destruction of alligators. Where there are plenty of gators, they say, there are plenty of fish. On this subject Jackson Lee once observed: "You cain't ketch no fish hardly where there ain't no gators. Over on Honey Islant P'rairie, when me an' Julian Godwin came ter a hole with a gator in it, we could ketch a-plenty er fish."

As conspicuous and interesting a creature as the alligator could not, of course, escape notice in the folk-lore of the region. One day, a good many years ago, when David Lee and I heard some bellowing while we were poling through the cypress bay between Billy's Lake and the Minne Lake Islands, he remarked, "If it don't rain within three days when a gator bellers, it's goin' ter be dry weather, they say." Years later, when Tom Chesser said, "I heerd some gators this mornin'," I thought to inquire, "Does that mean we're goin' ter have 'weather'?"

"That's whut the ol' folks say," he answered. "I don't know anything erbout it." On another occasion, after a pronounced outbreak of bellowing, I was interested to notice that we had a shower two days later! In Lone Thrift's opinion, "They gener'ly beller against a rain—a few hours before a rain." There may be as sound a reason for alligators bellowing in anticipation of rain as for tree-toads and frogs to

croak at such a time. Beyond a doubt rainfall creates favorable conditions for the egg-laying of amphibians, and Reese[29] speaks of the alligator's laying being deferred on account of an extreme drought.

A local wag once prescribed the oil from "a pint er gator brains" as a certain cure for rheumatism, well aware that his patient would not be likely to acquire that quantity of the notoriously small brains of this species.

It used to please the fancy of some of the Billy's Island boys to bestow particular names upon the occupants of certain gator-holes on Floyd's Island Prairie. In passing by, they would delight to grunt for their saurian acquaintances, to watch for their "blubbers," to "job" at them with their push-poles in a friendly way and to call them by such fantastic appellations as "He-catter," "Sally," "Goshen" or "Jim Lockey." The picture of one of these lads carrying on his frolics, while standing up in his boat and dexterously wielding his push-pole in a prairie gator-hole, is one of the pleasantest that my memory of the Okefinokee holds.

[29] P. 18.

PRESERVATION OF STEEL

By Dr. A. H. SABIN
NATIONAL LEAD COMPANY

It has always been known that pieces of iron or steel, when exposed to the weather, rust and are progressively destroyed by conversion into oxides, hydrates or salts; this also takes place under water. It has long been approved practice to prevent or retard this action by painting it; the paint should make a waterproof and impervious film. A gallon of paint will cover, in general, from 350 to 600 square feet, or an average film thickness of perhaps three thousandths of an inch or eight hundredths of a millimeter. It is probably impossible to apply this so as to be quite free of porosity, but when the film is dry (by oxidation) a second coat will so cover it that any breaks in the first are closed; the best practice calls for a third coat. When we think that we expect five or more years' protection against the weather from a film a quarter of a millimeter or a hundredth of an inch thick, it seems an extravagant demand; yet twice this time is often reached, and three times is not beyond the record.

Highway engineers and also, especially, railway men who have responsible care of steel structures are thorough in their painting requirements; they expect the metal to be clean beforehand from dirt, rust and scale. Their work is frequently inspected and they realize their responsibilities more uniformly than do those whose work is concealed, and their judgment is a safe guide.

Every one has seen composite structures made of concrete, which is an artificial rock, and steel posts and beams. The beams are erected first and then the concrete, in a liquid form, is poured into incasing wooden jackets where it hardens, thus giving a strength and rigidity greater than either would have alone. There is difference in opinion and in practice among engineers as to the painting of such steel before the artificial stone is formed around it. Some paint it with much care, and some do not paint it at all. This is one of the most extraordinary anomalies in engineering belief. Some of the best engineers think one way and equally good ones are opposed to them; there is no middle ground. No one doubts the value of good composite structures, and no one questions the usefulness of good paint by itself.

About the beginning of the present century concrete began to be considered as useful in constructive design, and its promoters, who as later experience has shown had sufficient ground for their general claims for its excellence and general utility, called attention to the fact that its expansion and contraction during (and due to) changes in temperature were the same as those of steel, and hence no temperature-stresses were likely to lessen the strength of composite members; and also that concrete acts as a preventive of corrosion because the cement in it is strongly alkaline, and iron does not rust when protected by alkali. Therefore, they said, it was not necessary to paint steel which was to be entirely covered by concrete. Also they claimed that the reenforcing value of the steel was dependent on its adhesion to the concrete, and that this was lessened by interposing a film of paint, so that it was actually better not to have it painted, quite in addition to saving the cost of paint and painting and the delay involved. They had a strong case.

But in the course of time trouble arose. Sometimes the imbedded metal did rust, and the almost irresistible expansive force of the chemical reaction burst the enveloping concrete layer, which sometimes appeared to be quite disintegrated. The repair of such breaks is difficult and costly and sometimes impossible. The break was explained by the original contractor as due to the impossibility of avoiding occasional imperfect mixtures when working with practical construction methods and the unreliability of labor to secure perfection in the mixing and application every minute; and while the improvement in mixing machines, better measurements of the ingredients and general standardization have probably been of good effect, yet the enormous use of this material, the necessary tendency to greater economy in the work and the rapidity with which such work is rushed all have effects in the opposite way, so that failures still occur and probably increase. It is obvious that a good rust-preventive paint in such places would have been of much value, probably enough in any one case of failure to have warranted its use on the whole structure. As to the effect of paint weakening the structure because of lessening the so-called bond between the steel and the concrete, there are things to look into. In the first place, some misleading ideas about this bond exist. It is simply adhesion; there is no chemical or other mysterious action; the pressure of the enveloping concrete does not lessen the adhesion of paint to metal, which is actually great, so that to remove it when well dried on, if desired, it is necessary to use the sandblast or to melt it with the blow-torch and scrape it while hot. Cement adheres to dry paint, but undoubtedly the presence of this elastic film makes it possible to pull a smooth rod of imbedded steel out of a block of perfect concrete more easily than if the paint were not there. But it has long been recognized by engineers that concrete also holds steel by its own strength and rigidity, so that bars for reenforcing are made with lumps, twists or other distortions to cause the separation of the concrete and the steel to depend, not on some uncertain bond, but on the composite strength of materials; and when riveted joints or irregular shapes are covered with concrete it is clear that the strength of such places depends on the strength of materials, and the stiffness of the joints is due to this construction and to the contraction of the concrete while setting which ensures a good fit. The adhesion of concrete is a real thing, and is a little more (how much depends on what kind of paint is used) if there is no paint; but it is fundamentally due to the form and strength of the concrete mass itself.

It has been said that concrete has the same thermal expansion as steel, but it is pointed out by the bridge engineer of the longest railway system in this country that while it may be that a concrete can be made of which that is true, practically concrete contains, as half its composition, local available rock or gravel, no two samples of which are likely to expand alike, and it is reasonable to expect stresses due to this cause, which push or pull incessantly as changes in temperature never stop, and these must loosen the so-called bond which is otherwise said to exist. In fact when old structures are demolished it is sometimes possible to scale off the concrete from the metal.

It is true that freshly made concrete is strongly alkaline; some of the combined calcium is set free as hydrates in the somewhat complicated chemical action which takes place when the ingredients are mixed with water. If minerals like felspar are part of the mix, it is not unknown to find potassium carbonate in the water which exudes from the surface. As iron does not corrode in the presence

of free alkali, the anti-corrosive value is ample when the concrete is fresh, but it is not found in concrete several years old. It is well known in testing laboratories that a well-made block of concrete (for example, four inches in diameter) well-aged, dried in artificially dried air, weighed, then submerged several days in water, then superficially well dried, always gains considerably in weight, showing that it is not impenetrable to water. While water will not visibly flow through it, as through unglazed earthenware, it nevertheless passes slowly, and the idea that it is waterproof has long since been given up. Thus free soluble alkali gradually escapes; and it is well-known that while fresh oil-paint does not make a good coating on new concrete, it is safely used on that which has been exposed to the air for a year or so. Well-dried paint, as that on structural metal, is not appreciably attacked, because a dried film (linoxyn) is resistant to dilute alkali. But the protective action of the alkali in concrete, ample when it is fresh and perhaps for a year or more, gradually disappears with age. The really permanent protection which it affords to imbedded steel is due to the fact that it keeps air and moisture away mechanically, and this is of great value.

It is often said by inspecting engineers that it is impossible to mix and pour a thousand tons of concrete without some defective places in it due to imperfect proportioning of ingredients, too much or too little water, unavoidable or sometimes careless mistakes in placing. Many such things may happen on a large job which has to be rushed through in minimum time. These things let air and water in to the metal. If it is unpainted corrosion takes place, and as the rust occupies more space than the iron from which it is formed, and the force of chemical action is great, the adjacent concrete is lifted off. This crumbling artificial stone holds water somewhat as a sponge or any wet cellular mass does; the rusting goes on. An area of more than a square foot of concrete, making a sheet an inch and a half or two inches thick, lifted an inch or two from the supporting metal, has been reported, not in a single instance but often. Indeed, the massive concrete of composite bridge piers and of building foundations has been made into a crumbling mass which had to be entirely removed. Such things ought not to happen, and probably some engineers think they secure entire safety by the precautions they take. But even if they do it is likely that they may admit that less thorough methods are common.

Concrete highways are from five to ten inches thick, roughly speaking. They reach temperatures of over 100° F. in summer and below 0° F. in winter; in the cold they show cracks. They are often reenforced with steel rods, perhaps half an inch in diameter. When a crack forms and the adjacent masses of roadway, perhaps twenty feet wide, continue to shrink, each as a single body, the crack becomes a visible and considerable opening. But what happens to the steel rods which cross it? In the state highways of Illinois, to mention a particular case of high-class work, these rods, when the road is under construction, are painted with a paint which never becomes entirely hard, and therefore acts as a lubricant, so that the rod may slip a little as the imbedding concrete contracts or expands. They are to give transverse strength and toughness, but not excessive rigidity, to the sheet of concrete. This is a different sort of construction from that of a steel and concrete building, and it suggests some further lines of thought. A good weather-proof paint becomes hard—not hard as steel, but perhaps hard as a soft wood—and will stand a deal of abrasion without much injury. Yet it does not become so hard as to be brittle. On a piece of iron

it will yield enough when the latter is bent to bend with it and its dry film is always a little elastic. It is likely that this slight elasticity may help to prevent the formation of wide cracks in the much smaller temperature-changes which occur in ordinary buildings, and no doubt it will prevent the corrosion which microscopic cracks in the cement might otherwise provoke.

The causes are many for the opposition to painting steel which is to be incased in concrete. The first is the added expense. Some people do not care about this; but many jobs are on competitive bids, the labor cost of painting is somewhat of an uncertainty and every thousand dollars scaled off from an estimate has weight in deciding a corporation, especially a new one, whether to go on or not. The designer is urged to cut down cost wherever he can. The decorator, who comes later, may perhaps have all the money he wants—but not the engineer. Then it is said that painting involves delay. It seldom does, but sometimes it may, a little, and every hour is precious. Back of it all is the widespread belief that steel in concrete never rusts. But many engineers know that it sometimes, even frequently, does, and the values involved are so great that every possible protection ought to be taken. Fundamentally, the whole matter needs discussion. The men who feel sure and who can speak from experience ought to consider each other's arguments and instances. The present writer, who has studied and observed these questions for forty years, holds that all metal should be cleaned and painted with the best material and in the best manner, and engineers who have built hundreds of bridges and been in charge of them twenty to thirty years say that no steel shall go into their work unpainted. Splendid buildings like the Woolworth Tower, the Stevens Hotel and the Palmer House have two coats of the best paint, with the best inspection, before any concrete is applied; and at the same time millions go into skyscrapers with little or no attempt even to clean the steel from rust and scale. Something is wrong, somewhere.

LIGHTNING: IS SEEING BELIEVING?

By H. A. ALLARD
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FROM earliest childhood thunderstorms have fascinated me, and I have always made it a point to keep all the phenomena of their coming and going under minute observation. When a youth on my father's farm in New England I spent entire nights afield watching the play of lightning from the most favorable vantage-points. In spite of the fact that I was wont to perch upon the highest points of cliff and rock to satisfy my insatiable curiosity to behold these awe-inspiring storms, the gods were kind to me, or perchance the laws of probability allowed no particularly unpleasant contacts with the mysterious electrical manifestations.

I have beheld many interesting phenomena in this lifelong association with these storms, and my love of the beauty and grandeur and the dynamics of their weird play over the earth has been one of the happiest chapters of my life. I have beheld many seemingly truthful phenomena with respect to the play of the lightnings, yet I wonder, now and then, if some of the phenomena I have seen represent reality, or some phase of optical illusion or perspective. I am putting myself on record, hoping some of these points may be clarified for me, for it is evident that truth from the scientific point of view is dependent upon the correctness of sensory impressions.

I may state first that I have been so unfortunate for some reason as never to have beheld yet any hint or semblance of ball lightning. I not only feel that such must have occurred, but I feel that there is no logical reason why an electronic flow may not in some unusual condition take on a localized spinning perhaps, rather than the usual spark or streak path. I feel, furthermore, that some people are much more prone to see ball lightning than others, and I think such proneness is to be expected from the idiosyncrasies expressed in our sensory and psychic make-up. There are intelligent people still existing among us who believe they have seen and communicated with ghosts and spirit beings.

I will now consider the ordinary streak, spark and flash forms of lightning, which every one may see. A variety of phenomena arises here, some probably dependent upon truthful sensory revelation, some perhaps more or less illusional. If I take the evidence of my optical impressions alone I must conclude that the lightning bolt or discharge from cloud to cloud or between cloud and earth may appear as a single spark, as a series of sparks, as a stream and as any combination of these.

The first of these, the single spark effect, gives naturally the impression of one brief flash. I have seen this form of lightning time and again, even in the same thunder-storm. It is best seen when the storm is at a distance during the day or in the evening before it is dark enough to cause severe blinding by the flash. This form of lightning can be considered the isolated spark discharge.

If we admit the possibility of a brief spark discharge, it is logical to consider possibilities of more than one successional discharge. Admit this, and we progress from the phenomena of brief spark to sparks of longer duration, thence to the stream discharge.

If my observational impressions are correct, I have hundreds, yes thousands of times, beheld all phases of these. I

have beheld them in the same thunder-storm. Some thunder-storms display a greater frequency of one form than another, and all appear to be more generally earth-cloud discharges. There is no good reason why such phenomena should not exist, and I have compared my own impressions with those of other observers beside me who saw the phenomena in the same way.

The stream form of lightning gives evidence of genuine reality to me. I have seen a ribbon-like streak fairly hang between sky and earth for an appreciable time as it seemed, and the next bolt appear as a transient spark, with no apparent continuity between sky and earth. If these have any illusional possibilities, then I must conclude that at one moment, or on one afternoon, I am particularly susceptible to visional illusions; at another time remarkably free from them.

There is another phenomenon of lightning discharge which has come under much discussion in the columns of *Nature* in the past and spoken of as progressive lightning, or multiple flash.[1]

It is the broken or repeated discharge, apparently following the same path between cloud and earth. A bolt occurs followed sometimes by several others in rapid succession along the same path, as it would seem.

I see no reason why such interrupted discharges should not occur, and my sense of vision presents them in various time sequences. The impression may be of the occurrence of one streak or of two or more successive streaks, perhaps four. Whether there may even be a greater number than this I can not say. Even here some types of thunder-storm exhibit much higher percentages of the repeated discharge than others. As some observers have contended, it is true that these repeated discharges are associated with distance, but it is doubtful if any form of lightning can be as truthfully seen and reported within a hundred yards as at a distance of five miles.

If once we admit the possibility of successive sparks or discharges in approximately the same path I see no reason why conditions of varying time intervals between them may not occur. On the one extreme, these would appear a succession of several rather widely separated streaks; on the other, where the intervening time intervals have become so short as to be inappreciable, the discharge would appear as a closed stream discharge. I have more than once noted displacements of some of the successive discharges more or less remote from the original path. Even though ionization of the path of the first discharge makes it easier for successive discharges to follow, it is evident that this path must be subject to more or less rapid displacements as a result of air movement.

There is another phenomenon which is far more puzzling to me. It has always seemed to me optically that there are great differences in the speed of propagation of lightning streaks. The isolated spark discharge always gives me the impression of extreme speed. On the other hand, the lightning streak in some storms often seems to meander with rocket-like impressive slowness along the horizon. If at all times the speed of the discharge is near that of light, I can not see why this phenomenon should be revealed at any time even though the streak traveled entirely around the earth. I have seen it stated that lightning completes itself in one seven thousandth of a second, and that no part lasts longer than approximately one thirty-five hundredth of a second. If, however, the validity of slow-traveling

[1] C. V. Boys, *Nature* (England), November 20, 1926; C. D. Perrine, February 19, 1927; Whipple, May 16, 1889, p. 71.

ball lightning is admitted, it is natural to infer that the actual speed of propagation of lightning may vary from this minimum to some condition of maximum speed.

Another point of some interest is the fact, now recognized as established, that the direction of propagation of discharge may be from earth to cloud or *vice versa*. My eyes had led me to conclude this long before I had seen the assertion scientifically established. Some time in the early nineties I well remember reading with great enthusiasm a magazine article asserting this fact, the proof as I remember being based upon photographic evidence. More than once I had gotten the optical impression, at least, of a rocket-like meandering streak passing skyward from the earth. The usual direction in all my years of observation, however, has been a propagation from sky to earth. The apparent slowness of the rocket-like type of lightning has given other well-marked impressions. Often a meandering streak, as it seemed to me, shot up from the earth, meandered far away along the horizon and descended to earth again, as it seemed, many miles away. Of course here it may be assumed that the perspective of distance has entered into the matter. If a distant thunder-cloud extended below the horizon, a streak originating in the clouds actually below the horizon line and merely passing into the zone of vision at some higher point would appear as having shot up from the earth into the higher cloud regions. Strangely enough this optical illusion, which was a feature of my experience on innumerable occasions, had so much of the semblance of reality that I was led by erroneous seeing to arrive at some degree of actual truth with almost irresistible finality. From these early impressions even as a boy I was content to believe that the lightning streak sometimes passed skyward from earth, and I was not far wrong, thanks to the untruths of the optical illusion. One of the later views of the direction of the streak emphasizes the fact that it is earthward and skyward at the same instant, the two ends meeting in mid-air one seven thousandth of a second later. I have no doubt but that the perspective of distance is responsible for my impressions of the bolt arising from earth, yet why should a rocket-like slowness come in to favor such an illusion when the greatest visible path is inconceivably small in comparison with the distance electricity can travel in a second of time? If the propagation of the streak is toward a median point from two opposite directions, why does the human eye and mind usually define the resultant path as a sky-to-earth discharge? Is it a phenomenon comparable to those optical shifts of perspective in the so-called ambiguous figure that make some geometrical arrangements of lines take a certain form at one instant, and some other emphasis of form at another instant?

Thunder-storms are strange, weird phenomena in many respects. In a particularly active storm I have more than once seen a bolt shoot to earth far in advance of the lagging rainbelt. In one instance in particular I was so much interested as to make inquiry regarding such a bolt, learning finally, from one observer, that it had struck a tree on his place long before the rain itself had reached his locality. Not infrequently in the higher clouds pushing up with clear-cut outlines into the blue skies I have seen the lightning streak pass actually beyond the cloud limits and terminate in the clear zone some distance beyond. Here, however, there may be present a zone of invisible moisture, for it is at these higher points that the scarf cloud may suddenly come into

expression, apparently almost flowing over the tops of the rounded cumuli or extending outward like a blowing gossamer veil.

I may mention some apparent behaviors of the branching discharge which have come into my optical experience. Some bolts give the impression of an unbranched flame ribbon between sky and earth; others become much branched. It has always seemed to me that, in some instances, minor side sparks or streaks were induced which directed themselves toward the main discharge; in other instances, these side branches appeared to arise from the main flash and pass outward. From optical impressions I should most assuredly have said both conditions could occur.

There are other interesting features of thunder-storms which I have observed, bearing on the individuality of the storm as reflected in the character of the thunder and other attendant phenomena. Space, however, will not permit of a discussion at this time.

FOREST-FIRE RESEARCH

By H. T. GISBORNE

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FIRE is one of the three great natural causes of wastage of forest crops. Entomological and pathological causes—the other two—have long been the subject of extensive scientific research. It is only in recent years that a beginning has been made in the scientific investigation of forest fires, their cause and effect relationships and the possibilities of reducing the resultant losses by better methods of fire control based on more detailed knowledge of the fundamental factors involved. The control of insects and fungi is based on the science of forest entomology and forest pathology. We practice fire control but as yet we have no science of forest pyrology.

According to a recent article in the *Revue des Eaux et Forêts*[1] very little research has been devoted in Europe to these fundamental factors controlling the behavior of fires. In all countries there has been much study of the agencies that cause fires to start, but in the United States the need is now clearly recognized for studying also the natural conditions which must be favorable in order to permit these various agencies to start fires. Unless natural conditions are favorable forest fires can not be started, can not spread and can not do damage. And when there is no danger of spread or damage then there is no need for attempting to control or influence the agencies that start fires. On the other hand, when natural conditions are favorable to the spread of fire then there is need of controlling the causative agencies and then there is need of preparing to fight fires in direct proportion to the effect of the natural factors. When these factors are most favorable to rapid spread this need is greatest. It is rather obvious that for most efficient fire control, meaning prevention, detection and suppression, it is highly desirable not only to understand fully the conditions that cause fire danger to vary, but also to measure these variations and to modify our human efforts accordingly.

Practically every forest region in the world is subjected to periods when fires are very uncommon, alternating with periods when fires are more common. These latter periods are called fire seasons, and they are known to vary in degree of danger one season with another. It is uniformly true that the safe periods are characterized by weather which is wetter and colder than the fire seasons, which are the warmer and drier portions of the year. Bad fire seasons likewise are usually characterized by weather which is warmer, drier and windier than the easy seasons.

All fire seasons begin when the forest materials lose enough of previously accumulated moisture so that they become dry enough to support the process of combustion. As the season develops and the fuels lose more and more moisture due to still hotter and drier weather the degree of inflammability increases and finally reaches a peak for that season. Then as cooler and more humid weather occurs the forest materials, both dead and alive, absorb and retain more moisture and become less and less inflammable. Ultimately, heavy rains supply sufficient moisture so that the forests

[1] L. Lavauden, "Recherches techniques sur les incendies des forêts," *Revue des Eaux et Forêts*, October, 1928.

become too wet to burn, and that fire season is ended.

In all these transitions from non-inflammable to extreme inflammability and *vice versa,* the changes are due largely to decreased or increased moisture in the fuels. And in all these cases the weather is the obvious control of these changes in moisture content. Apparently any research designed to determine the causes of that effect which we call fire danger must consist of investigations of the inflammability of forest materials as influenced by their moisture content. This seems to be the first logical step from first danger back toward its controls. Clements has stated that "In all cases the best scientific method in analysis seems to be to deal with the immediate cause first and then to trace its origin as far as possible or profitable." As change of moisture content has been proved[2] to control the ease of ignition and the combustion of forest materials, the immediate causes and first subjects for fire research would seem to be the moisture contents of these fuels and the exact effects of moisture content on inflammability.

As has been indicated above and as proved by research already done,[3] the weather is the control of the moisture content of forest fuels. A great amount of research seems to be needed, however, to determine the exact moisture content of each important type of forest fuel as it is controlled by precipitation, temperature, humidity, wind and sunshine. Some progress has been made, it is true, but the bulk of this work still lies ahead of us.

Then comes the question: What controls the weather? And here we pass out of the field of forest-fire research into the realm of meteorology. But this is one of the most essential links in the chain of evidence which must be completed before we are able to put our knowledge to work so that more efficient protection can be given to our forests. It is of some value to know that moisture content determines the degree of inflammability, hence rate of spread of fire and hence fire danger. If we know the degree of inflammability resulting from a particular moisture content of a certain fuel and if we can conveniently measure the moisture contents of that fuel, then we have made some progress. We can measure existing danger and be sure of our pronouncement, instead of conjecturing about it and making numerous errors. Likewise, if we know that a specific combination of tempera-

[2] J. S. S. Brame, "Fuel—Solid, Liquid and Gaseous," Third ed., 388 pp., illus., London and New York, 1924.

"Measuring Forest-fire Danger in Northern Idaho," U. S. D. A. Misc. Pub. No. 29, 63 pp., illus., October, 1928.

L. F. Hawley, "Theoretical Considerations regarding Factors which Influence Forest Fires," *Journal of Forestry,* vol. 24, no. 7, November, 1926.

"The Use of Wood for Fuel," U. S. D. A. Bulletin 753, 40 pp., illus., 1919. Office of Forest Investigation, U. S. D. A.

[3] C. G. Bates, "Evaporation as a Simple Index to Weather Conditions," *U. S. Mo. Weather Rev.,* 51: 570–1, 1923.

H. T. Gisborne, "Using Weather Forecasts for Predicting Forest-fire Danger," *U. S. Mo. Weather Rev.,* 53: 58–60, February, 1925.

J. V. Hofmann and W. B. Osborne, Jr., "Relative Humidity and Forest Fires," 12 pp., illus., 1923. U. S. D. A. Forest Service, Washington, D. C.

J. A. Larsen and C. C. Delavan, "Climate and Forest Fires in Montana and Northern Idaho, 1909 to 1919," *U. S. Mo. Weather Rev.,* 50: 55–68, 1922, illus.

E. F. McCarthy, "Forest Fires and Storm Movement," *U. S. Mo. Weather Rev.,* 52: 257–259, illus., 1924.

E. N. Munns, "Evaporation and Forest Fires," *U. S. Mo. Weather Rev.,* 49: 149–152, illus., 1921.

W. B. Osborne, Jr., "Fire-fighting," in Western Forestry and Conservation Association, "The Western Fire Fighter's Manual," chap. 7, 66 pp., illus., Portland, Oregon, 1919.

S. B. Show and E. I. Kotok, "Weather Conditions and Forest Fires in California," U. S. D. A. Circ. 354, 24 pp., illus., 1925.

ture and humidity causes a particular moisture content in a fuel, then from the mere measurement of temperature and humidity we may be able to state that the existent atmospheric conditions will result in a certain degree of fire danger for it within a specified period of time. But such periods, which depend upon the rate of change of fuel moisture according to existing atmospheric conditions, are at best only matters of a few hours. Consequently, the mere measurement of temperature and humidity can not serve as a forecast of impending inflammability far enough ahead to give time to change much action in fire control.

The essential and fundamental step which must be taken, if we are to change our plans in fire control to meet changing degrees of fire danger, is the prediction of each of the various weather elements at least thirty-six hours in advance and preferably for several days. When the weather can be accurately predicted in detail for days ahead, when the effects of each of the weather elements on the moisture content of each of the fuels are known and when the resultant degrees of inflammability can be predicted on the basis of the weather forecasts, then the forest protective force can be increased so that fires may be found and extinguished while still small, or if conditions are favorable the force may be reduced or put on other work so that the expense of protection can be decreased. Then, and then only, will it be possible to obtain successful fire control at the lowest possible cost.

To achieve this goal will require the best efforts of trained research workers for a long period of years. But the results already obtained, from a very small force of investigators, prove that progress has been made and indicate that investments in this type of research will be highly profitable. Time permits the mention of but a few of the most outstanding results and the indication of only exemplary types of problems as we see them to-day.

A little over ten years ago, S. B. Show, in California, and J. A. Larsen, at the Northern Rocky Mountain Forest Experiment Station, both determined that when the coniferous forest duff, composed of dead tree leaves, twigs, etc., has less than 10 per cent. moisture content, it can be ignited readily with a match and that the fire will spread. They called this the danger line. Show also determined experimentally that the rate of spread of fire varies as the square of the wind velocity, other factors being constant. Five years later Hofmann and Osborne determined that when the relative humidity of the air is below 30 per cent. or 35 per cent. forest fires spread rapidly in the Douglas fir region of the Pacific Coast; at higher humidities they spread more and more slowly. Thus, the importance of humidity was established and another danger line determined for at least one timber type. Meanwhile Larsen had drawn a line at two inches of rainfall per month, below which fires are more common, above which they are more uncommon in the northern Rocky Mountain region. Both Munns and Bates pointed out the fact that the rate of evaporation, as controlled by humidity, temperature and wind, exerts a marked influence on the rate of drying of fuels following rains. More recently the writer has isolated six degrees of duff inflammability according to moisture content. Temperature, humidity and evaporation rate have likewise been correlated with duff moisture and inflammability so that the effects of each of these weather factors may be classified at least into four degrees of danger. An instrument has been invented and developed for measuring duff moisture content *in situ* so that no time is lost in determining the existent degree of duff inflammability.

Lightning, the greatest single cause of forest fires in the northern Rocky Mountain region, is being traced to its lair and on its ravaging voyages by the use of all forest fire lookouts in the western United States. Last year over 4,500 observations of storm occurrence, path, characteristics and resultant fires were made in the northern Rocky Mountain region alone. And for the last fifteen years, with constantly improving effort and results, the U. S. Weather Bureau has been studying the weather in the forested regions and modifying the forecasts so that they are more and more localized and dependable.

As a result, the American forest-fire protective organizations have become more and more fire and weather conscious. The most alert officials in charge of fire control are beginning actually to depend upon instrumental measurements of existing danger and forecasts for the future. Merely as examples: last spring over forty men were moved from trail and telephone maintenance and construction to lookouts, smoke-chaser and fire-patrol duty on one national forest when duff hygrometer measurements showed that this fuel had dried to a condition of medium inflammability—10 per cent. to 13 per cent. moisture content. In another case fuel-moisture and atmospheric measurements showed that fire danger was greater than commonly estimated by experienced men. On the basis of these measurements an emergency was declared and the forest protective force was greatly increased. In still another case the thirty-six-hour weather forecast received on a large fire which was being fought indicated a change in wind direction from southwest to north. Tactics of suppression were modified accordingly, one head of the fire which had been unapproachable was attacked and an entire mountain side which officials had despaired of saving was saved from destruction.

These and many other cases show very clearly that progress is being made in forest protection as a result of fire research, but there is a great field of effort still untouched. We have in the past attacked the most obvious problems; many of these have also been the most superficial problems. Our previous research has been confined largely to the production of minor improvements in the practice of fire control, checks on judgment—in the form of measurements to replace guesses, new information for current application such as weather forecasts for a few hours of time, etc. In the meantime, we have almost entirely neglected the fundamental factors of more universal and enduring application. Although the original working plan, designed to control this research work in the northern Rocky Mountain region, outlined some of these fundamental problems and recommended their attack, the urge for more immediately applicable results has prevented progress. Many of the more or less superficial problems root, however, in fundamental conditions which must be known and studied in detail before the desired goal can be attained.

For example, consider the spread of forest fires. Superficially the desired knowledge would seem to be obtainable merely by measuring actual rate of spread of fire and the fuel volumes, arrangements, moisture contents and atmospheric factors which contribute to this spread. But in such a study can we overlook the Stefan-Boltzmann law of physics ($E = sT^4$), which says that the radiation of heat—from a perfect radiator—varies with the fourth power of the temperature of the radiating body? We have found the temperatures of burning duff to be as high as 376° C., while in a burning slash pile a maximum of 860° C. has been measured in some preliminary work. In these two cases the hotter fire had little more than twice

the temperature of the cooler and might be judged as radiating twice the heat, yet according to the Stefan-Boltzmann law the heat actually radiated by the slash fire was more than nine times that given off by equal radiating surface of the burning duff. As the radiant energy of forest fires is often sufficient to transmit the ignition temperature to fuels separated from the fire by the width of constructed fire trenches, it is obvious that such marked differences in radiation as have just been described can not be neglected in any thorough study of rate of spread of fire.

In this same field of investigation we know nothing whatever of the exact wave-lengths of the energy liberated by the combustion of forest fuels. Yet when the major radiation lies between 3 μ and 4 μ (30,000 to 40,000 Ångström units) at about 700° C., the emissivity is less than one twenty-fifth of what it is when the temperature of the radiating body is about 1,400° C. (white heat stage) at wave-lengths of about 2 μ. And all these radiations are outside the visible spectrum, entirely incommensurable except instrumentally. In fact it is probable that only an infinitesimal proportion of the radiation which contributes to the spread of forest fires lies within the range of ocular visibility where it would be observed and accounted for by superficial investigation.

It is obvious that temperatures of combustion and the emissivity of our fuels undoubtedly are important factors in the rate of spread of forest fires. It is likewise apparent that we must consider much more than the superficial factors if we are to understand and make full use of knowledge of rate of spread of fires. We can not hope to correlate the superficial factors into useful knowledge without giving full consideration to the fundamental laws of combustion. This does not imply that our research should be devoted to the extension and amplification of these laws; it merely asserts that research limited to superficial conditions can not be expected to produce more than superficial and oftentimes temporary results.

Many more cases of similar kind could be cited to illustrate both the progress already made in forest-fire research and the great field which lies unexplored ahead of us. The problem is recognized as of paramount importance to the successful practice of forestry in many regions. We have our sciences of forest entomology and forest pathology as bases for the protection of forests from insects and fungi, but our fire-fighting will not be based soundly on the science of forest pyrology until we have profited by a great deal more and far better fire research.

BIPED HABIT

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IN the pine forests of northern Arizona stands a frame building intended for a barn. The ground is deep with snow. Icicles hang from the eaves, and from a tall chimney a curl of blue smoke rises in the clear sunny atmosphere. You might not be surprised to find a still hidden in this environment, but you would be more surprised to see the actual contents, for this barn houses the San Francisco Mountain Zoological Station of the University of Pennsylvania.

In two sunny south rooms, cages six feet long are suspended from the ceiling, and in these cages are white rats hopping about on their hind legs like happy little kangaroos or waddling around like woolly bears, and on the edge of the food bowls perch half-grown rats nibbling up the mash of corn, sunflower seeds and hamburger. In other cages the adults are busy carrying the food into their nests by mouthfuls, for the hoarding instinct is strong in the white rat. These rats form part of an experiment designed to test if bipedal habit will modify the shape of the hind limbs of the albino rat.

As a means of locomotion, vertebrates have taken to their hind legs fourteen or more times. Each time adjustments in the structure of the limbs seem to have resulted. Of all the changes observed, it is not yet possible to present a complete picture. Certain general principles stand in relief.

Above the Amphibia each class of vertebrates contains biped members, yet no one has made a comparative study of the mechanics of bipedal locomotion. A superficial investigation will show that the use of the hind limbs differs among bipeds. Leaping or hopping bipeds, such as the kangaroo, kangaroo-rat and jerboa, can be distinguished from those that walk or run, as the chimpanzee, gorilla and man. Some are plantigrade, as is man with his heel on the ground. Others are digitigrade, with the heel off the ground, such as the jerboa, or the kangaroo-rat. In pictures of the kangaroo the heel is figured on the ground. However, during locomotion the heel is

FIG. 1. A BIPED WHITE RAT

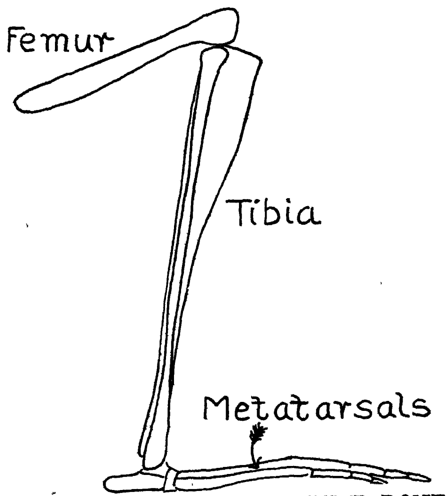


FIG. 2. KANGAROO HIND LIMB BONES

raised and does not touch the ground between jumps. The kangaroo, therefore, is digitigrade (Fig. 2). In those animals which jump, the bones of the upper and lower leg form an acute angle at the knee. In the walking and running forms, the angle is apt to be obtuse. So we must distinguish the leaping forms from the walking forms, the plantigrade from the digitigrade, for the mechanics of each case differ.

In another way can bipedal animals be classified. The kangaroo or kangaroo-rat is completely biped, while the bear and certain lizards are occasionally so. Where comes old man frog? His chief organ of locomotion is his hind legs, but at rest he is on all fours. No one would call him bipedal.

So we have all grades from the complete biped to the obligatory quadruped. A study of biped habit is not a simple thing. It might be profitable to mention a few of the groups of animals members of which have taken to their hind legs. Four orders of reptiles contain biped forms. All birds are biped. In Mammals bipeds are found in four of the orders: in the Marsupials, as the kangaroo and wallaby; in the Insectivores, as the elephant shrew; in the Rodents, as the jerboa, kangaroo-rat, Siberian jumping rabbit and the Cape jumping hare; in the Primates, as Tarsius and man.

As illustrated in Figs. 2 and 3, the hind limbs of all vertebrates are constructed on the same general plan. In this study we center our attention on the leg bones, femur and tibia, as well as those foot bones called metatarsals.

W. K. Gregory[1] has measured the bones of the hind limbs of the hoofed animals (Ungulata). He showed that the legs adapted to running have relatively short femurs, as in the deer, while legs of heavy animals which waddle had long femurs. In the latter group we have the hippopotamus and elephant. We find the same condition among digitigrade and plantigrade bipeds. The lively animals that dance on their toes have relatively shorter femurs than the slower bipeds that slump around with their heels on the ground.

When we consider the relative lengths of the bones of the hind legs, the femur and the tibia (Fig. 3), we will discover that the ratio derived by dividing the length of the femur into the length of

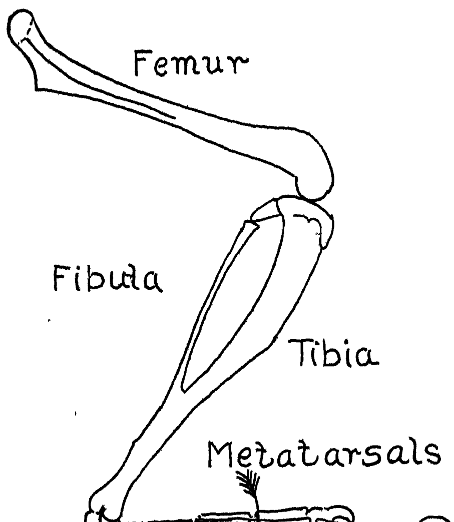


FIG. 3. STRUCTURE OF THE HIND LIMB OF ALBINO RAT

[1] W. K. Gregory, *Annals* of the New York Academy of Science, 22: 267–294, 1919.

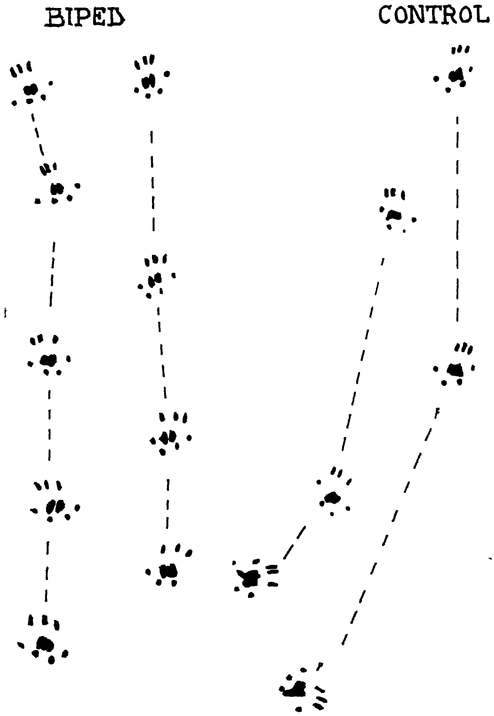


FIG. 4. FOOTPRINTS

the tibia has rather a constant relation in certain bipeds. If we jot down these ratios in a table comparing the biped and quadruped members of different orders of Mammals, (1) biped kangaroos against the quadrupedal oppossums, (2) biped rodents, jerboas, kangaroo-rats, against quadrupedal rats, mice and squirrels, (3) the occasionally biped bear against other Carnivora, (4) the quadrupedal lemurs and monkeys against the chimpanzee, gorilla and man, we find that the femur is shorter than the tibia in biped marsupials and rodents, and is almost equal in the quadrupeds. In the biped types of Carnivora and Primates the femur is longer than the tibia and nearly equal in the quadrupedal forms. It is clear we have two types of bipedal limb. In the digitigrade forms, the femur is relatively short, and in the plantigrade forms the femur is relatively long.

Gregory[1] found that, in general, hoofed animals which are lightly constructed for running, as the horse, have longer foot bones, metatarsals, than the heavy walking forms such as the rhinoceros. We have the same thing true in biped locomotion. The leaping bipeds have very long metatarsals, as in the kangaroo-rats, while the bipeds that walk, such as man, have short metatarsals. Sometimes an apparent exception proves the rule. If we examine the hind foot of that curious little primitive primate, Tarsius, found in the Philippines and Borneo, a little leaping biped with certain anatomical structures lying between the lemurs on one hand and the anthropoid apes on the other, we will notice that the metatarsals are short. However, the foot is long as in other leaping bipeds, and the length is derived from two bones of the ankle, the calcanium and navicular. The net result is the same as in the rodents, but the structures involved are different.

To test if the structural changes outlined above were a direct response to biped habit, years ago Fuld and Knickmeyer[2] removed the fore limbs of seven puppies from four litters. When these puppies, which had to get about on their hind legs, became adults, they were killed and the hind limbs studied. It was found that the femurs were relatively shorter than the femurs of their unoperated brothers and sisters. In other words, they approached the kangaroos in limb character.

A few years later, Renaud[3] in Paris observed, attached to a circus, a dog which had been born without fore

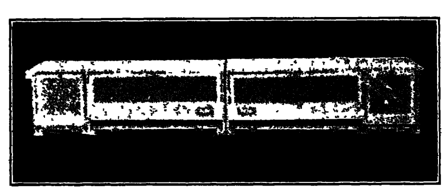


FIG. 5. CAGES

[2] E. Fuld, *Arch. Entw. der Org.*, Bd. 2, No. 1, 561, 1901.

[3] F. Renaud, *Biologica*, No. 10, October 15, 1911.

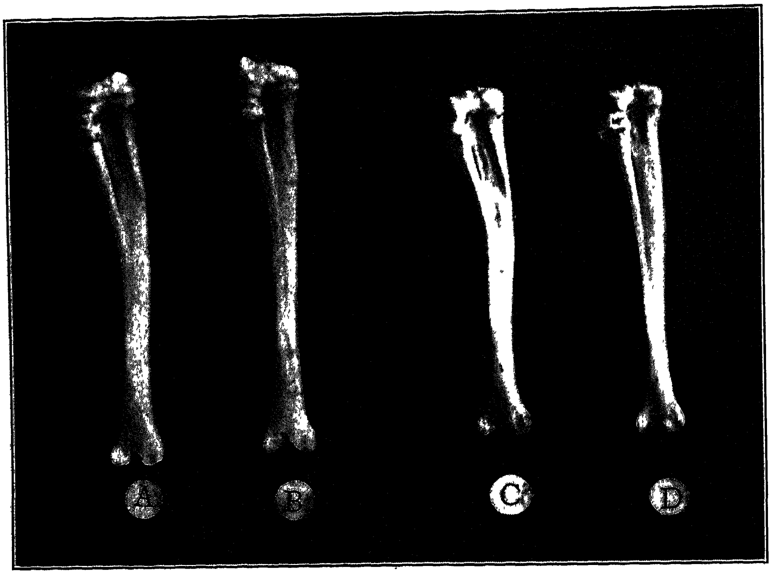


FIG. 6. TIBIA OF BIPED AND QUADRUPED

limbs. When this dog died he procured its carcass. Comparing its hind legs with that of other dog skeletons he found that its femur was relatively shorter, just as Fuld and Knickmeyer discovered in the artificially biped dogs.

Since these experiments have attracted the attention of zoologists interested in the Lamarckian theory of evolution,[4] the author thought that a verification was necessary, so he selected the white rat, to which man is already deeply in debt, as a convenient subject.

The fore limbs of white rats were removed from half the individuals of over fifty litters. This operation was made shortly after birth while the young rats, blind and helpless, were under the effects of ether. Over two hundred rats took part in the experiment (Fig. 1). These rats were raised in specially constructed cages six feet long so that the animals had an opportunity to hop about and so get plenty of exercise (Fig. 5).

When the rats were full grown, five to seven months old, they were killed, the skeletons cleaned up and the bones of the hind legs measured together with the skulls. The measurements of the biped bones were compared with the bones of the normal brothers and sisters of the biped animals, the controls, which were killed at the same time.

As a result of this study in which the significance of the difference was tested by statistical methods, it was found that the biped rats (1) have a femur relatively longer than the quadrupedal control, (2) that they tended to become knock-kneed by a bend in the tibia below the knee joint, (3) the fibula became bowshaped and (4) the ankle joint wider. The spraddled legs, widespread toes and accompanying structural changes seem an adaptation to greater stability by furnishing a broader base on which to stand[5] (Fig. 6).

By inking the feet of biped and quadrupedal rats taken from the same litter, it was found that the feet of the bipeds are placed further apart than those of the controls (Fig. 4). This distance in the bipeds proved to be nearly 30 per cent. greater than the quadrupedal distance. Also, the toes of the biped are

[4] H. F. Osborn, *Am. Nat.*, 56: 140, 1922.

[5] H. S. Colton, *Journal of Experimental Zoology*, Vol. 53, No. 1, 1929.

spraddled more than the controls', and further, the stride of the biped was but half that of the control.

It was a mean trick to play on a rat, which is a very cleanly animal, but it confirmed the conclusions that the structural changes were an adaptation to greater stability.

A statistical study of the metatarsal bones showed no significant difference between the experimental and the control animals.

That the femur becomes relatively longer in the biped than in the control rat is an interesting readjustment. It is in the man direction, not like that in the kangaroo or kangaroo-rat. The bipeds are, however, plantigrade like men and bears. Although they frequently leap, the more regular mode of locomotion is walking. Frequently losing their balance, they fall forward on their chests. Some individuals get about much better than others. One rat was so active and well adjusted that she could jump from the bottom of a bucket and land on the rim, a distance of ten inches.

The work on the white rat leads to the following conclusions: The hind limbs are slightly modified by biped habit. The relative length of the femur is modified in the man direction, not in the kangaroo direction, as in the case of the dogs reported above. But then the rats are plantigrade, like the bear and man, while the dogs are digitigrade, like the kangaroo. Maybe here we have a correlation. It seems that the modifications are in the direction of greater stability.

One would expect a structural readjustment to a changed environment, but as no breeding experiments have been reported, the experiments throw no light on the Lamarckian factors in evolution.

HYPNOTISM TO-DAY

By Dr. M. RUSSELL STEIN
NEW YORK CITY

STRANGE is the breadth of human credulity, but stranger still are the varieties of antithetical beliefs lodged within the walls of a single cranium. It is doubtful whether any age entertained notions as contrasting as those embraced by the moderns. An explanation of the apparent paradoxical gullibility to-day might be sought in the changes effected by machinery on western civilization. The transition period from an age of credence to an age of science offers a diversity of experience which never before was possible. From a single modern man can be dissected vestiges of civilizations of the past, for he is but the concretion of the history of mankind from the stone to the radio age. His bundle of habits and customs cries out the cultural background of his society.

Within the very shadow of a medical center there rises a magnificent temple to Christian Science. While William Jennings Bryan immortalizes the Scopes trial Millikan weighs the electron. While Aimée Semple MacPherson saves the souls of thousands of strayed lambs of the Lord, Banting and MacLeod isolate insulin and save the lives of as many diabetics. The corner-stones of world peace are laid synchronously with the launching of sturdy battleships. In the same city there live psychologists and phrenologists, physicists and spiritualists, chemists and alchemists, physicians and voodooists, astronomers and fortune-tellers, logicians and Holy Rollers. The fundamentalists entertain no admiration for the biologists, and the physicists abhor the scourge of spiritualism. And in this maelstrom of skepticism and gullibility, sincerity and deception, bigotry and heresy, the eventful pages of the history of hypnotism are written, exploited as a phenomenon and neglected as a science.

There are many popular misconceptions concerning hypnosis, and there are still some reputable psychologists who think it is a form of spiritualism. The majority of people have heard of hypnosis through various non-scientific channels, and their knowledge and opinions on the subject are cloaked with discredit and mystery.

Hypnosis, more than any other field of psychology, has been deprived of scientific investigation because of popular disrepute. For over a hundred and fifty years its association with charlatanism and magic has blackened the reputations of those who dabbled with it. College professors are still requested by their orthodox boards of trustees to limit their experimentation in hypnosis. In one instance the professor of psychology in a large Eastern university was threatened with arrest for demonstrating hypnotic phenomena to his students. Physicians are taught little or nothing about it because of the tabus by the medical societies. Psychologists have discarded it as a technique for psychoanalysis. Academicians have played with it as they would with an interesting toy. From every angle research in this field has been stifled. Hypnosis enjoys little respectability in America and has heretofore been relegated to theatrics and occultism. The average instructor in psychology passes over hypnosis as a Sunday-school teacher passes over "filthy" passages in the Bible.

If hypnosis had not been exploited by so many mountebanks in the past, the importance of the mental mechanisms

there involved would now be widely recognized. Experiments or demonstrations in this field are unfortunately referred to as "hypnotic séances," a connotation linking them with "spiritualistic séances." Hypnotism is not spiritualism. The only relation it bears to spiritualism is being confused with it.

The public has been fed with cheap and misleading literature on the subject. Popular ten cent pamphlets lay bare the mysteries of hypnotism to the credulous readers. The works of Bramwell and Moll are read sparingly. Correspondence courses unveil life's mysteries to you for the "small sum of fifty dollars." Character building and the improvement of sales ability are both included for the same fee. "You learn how man's innate goodness can be proved by hypnotism . . . and how to be irresistible to the opposite sex." Photostatic copies of testimonies verifying these claims are printed in the catalogue. You are taught how to hypnotize in public, which will make you the attraction at social parties. After impressing the reader by the rare privilege of being able to take the course with this particular professor, the prospectus emphasizes the fact that at the end of that course one receives a finely engraved diploma signed by the professor himself, whose hypnotism acts are always headliners at vaudeville shows!

Thus a fertile opportunity for investigation into a psychological phenomenon has been carried away on the great band-wagon of exploitation.

On the stage and at parlor "séances" the object of the hypnotist is obviously to make the demonstration as sensational as possible, amazing the audience with his formidable will power. The resulting extravagant claims of these entertainers have led to a complete denial of the validity of hypnotic phenomena. Hypnosis has a shady reputation, and in an effort to lift it from public life to the laboratory for investigation two obstacles are encountered, either it is not believed in at all, or when it is, it is misunderstood. Once in the laboratory we find ourselves faced with problems at the very core of individual and social psychology. It rapidly involves questions of consciousness, sensations, memory, learning, attention, fear and love. And before long we are sunk in the dilemmas of free will, suggestion and hysteria.

Occasionally one reads in the newspapers of a spectacular operation performed under hypnosis without the use of a drug anesthetic. This makes a big scoop for the reporters, who invariably sensationalize every detail of the event. The write-ups bring to the involved hypnotist a welcome popularity (for publicity has a rare value these days). A casual reader asks, "If hypnotism is that efficient as an anesthetic why does it not replace ether?" The answer is simple. A deep surgical anesthesia can be produced on only a small percentage of persons, and at that, with difficulty.

The probability is that in the last century clinicians and amateur enthusiasts have exploited all the hypnotic phenomena. The pseudomiracles have been discovered, duly misunderstood and speculated upon. There is now, however, an important movement among experimental psychologists in the United States to subject these miracles to controlled scientific analysis. Professor Hull, of Yale University, is already well on his way in an extensive research to determine the relations between hypnosis and other psychological reactions and to measure its clinical possibilities and limitations.

Hypnosis in the last half of the nineteenth century had its day as the panacea for man's maladies. Are illnesses actually cured by hypnosis? Has not hypnosis been a valuable therapeutic agent? In the great mass of literature

since the time of Mesmer we find hypnosis being used to cure anything in the gamut of human ills, from a cold to the last stage of syphilis.

To-day there are still some physicians devoting their entire practices to work in hypnosis. As specialists in their field they should know more about the medical possibilities of hypnosis than do their fellow practitioners, who have gazed, some with admiration and some with reprehension, at their clinics. Like most specialists, the hypnotists have overestimated the importance of the type of therapy they advocate. This exaggeration, coupled with the radical beliefs involved in hypnotic treatment, irritates the conservative majority of physicians. Antagonism and disapproval flared up against the mesmerists at the end of the eighteenth century and have been burning ever since. The conflict with established medicine was already at red heat when the word *hypnotism* was coined by James Braid in 1843. The more intensely the hypnotist fought for his principles the more significant they appeared to him to be. James Esdaile, who had performed thousands of major and minor operations under hypnosis at hospitals in India, was but one of the many unfortunate victims of bigoted professionalism. His work was enlightening, but the medical journals refused to publish his reports. Esdaile wrote to the profession in 1852:

To pretend that there is a *free medical press* in Great Britain is a mockery and delusion. And the proof of this is that medical men, who pledge their unblemished private and professional reputation for the truth of their statements, are not allowed to be heard by you in your professional organs, if what they advance is contrary to the prejudices and foregone conclusions of the editors.

The early psychotherapists saw in the sudden development of the art of hypnosis the dawn of a new scientific era. At last light had been thrown on the obscure problems of medicine. To-day the sophisticated physician looks back with scorn at the fanaticisms and shortsightedness of these men. But one must bear in mind that the annals of medicine are by no means a glorious procession of scientific achievements. There is an unbroken series of fads and faith cures from the primitive fetish to the modern bread pill. Faith cures actually do cure and will continue to do so until man stops believing. The element of faith plays its part in the efficiency of any therapeutic agent. The loss of interest in hypnotic therapy in America in the last thirty years was not due to the formal disapprobation of the dignified medical societies but to the advent of Mrs. Eddy's bigger and better system of therapy, Christian Science. It will take another half century before the medical profession fully appreciates the importance of the rôle played by social relations, belief and faith in bodily health.

The fad of hypnotic therapy is referred to as "the folly of the nineteenth century" and "the great psychological crime," but from it has evolved a wealth of experimentation and knowledge of abnormal psychology. From it has grown a new science, the professors of which speak of hypnosis in equivocal terms.

THE PROGRESS OF SCIENCE

THE INSTALLATION OF DR. COMPTON AS PRESIDENT OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Dr. Karl Taylor Compton, eminent scientist and member of a family of distinguished educators, was inaugurated eleventh president of the Massachusetts Institute of Technology on June 6. By his side as he took office was Dr. Samuel Wesley Stratton, who has been president of the institute since 1923, and who now becomes chairman of the corporation.

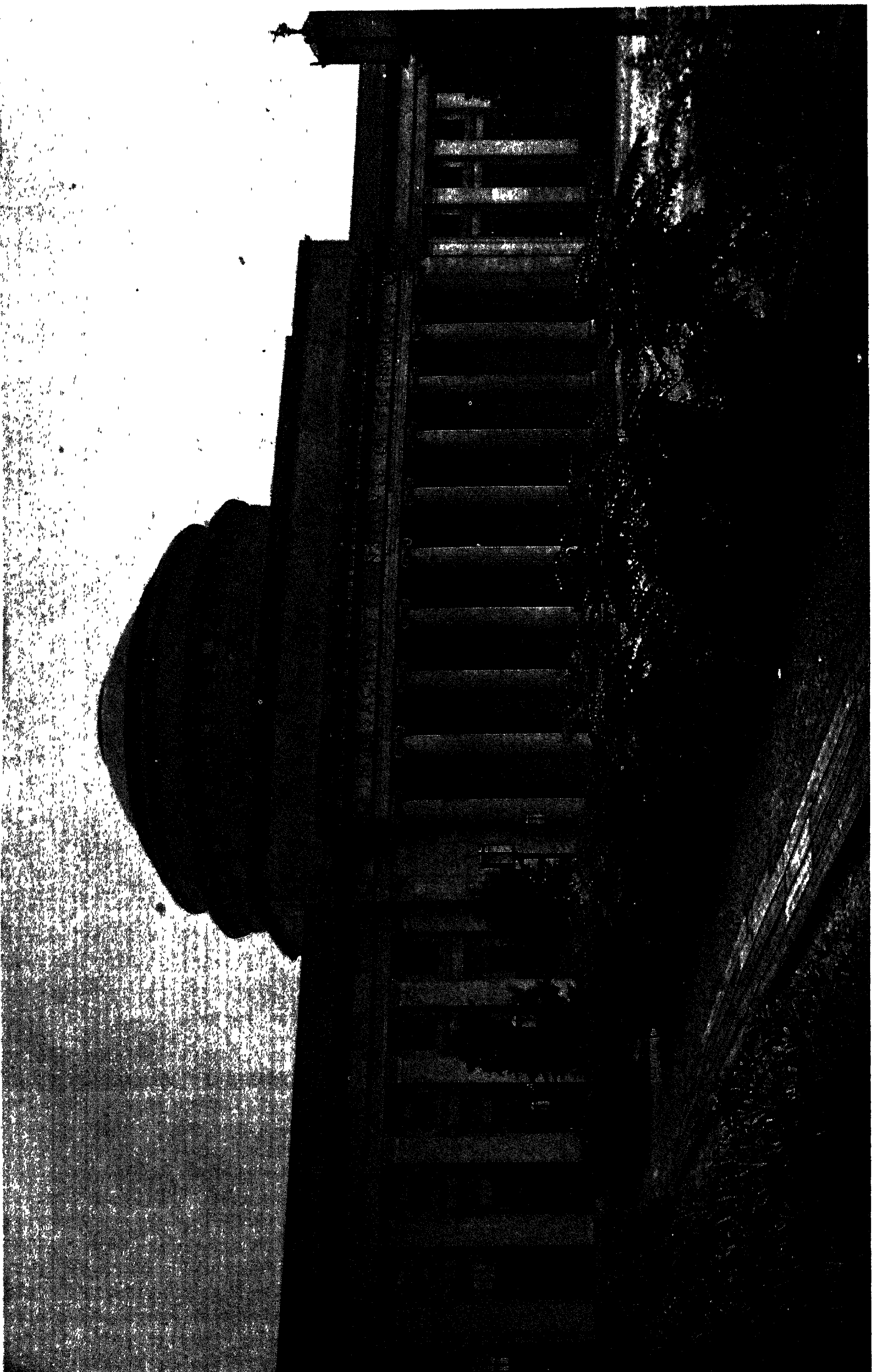
More than 4,000 guests witnessed Dr. Compton's inauguration, and of these at least 2,000 were alumni of Technology, gathered here for the All-Technology Reunion which opened on June 6. The official delegates included representatives of the leading colleges of the country, and many from abroad, as well as the learned and professional societies, high army and navy officers and officials of the state and city governments of Boston and Cambridge.

Eastman Court, the great quadrangle formed by three sides of the main group of Technology's academic buildings, was the massive setting for Dr. Compton's inauguration. Pink and white rhododendrons in full color marked the borders of the broad lawn on three sides, and at the north end of the court the giant pillars of the main colonnade surmounted by Technology's great gray dome formed a majestic background for the ceremony.

The platform for the presidential party and delegates was a structure of striking architectural beauty. It was pearl gray in tone, carrying out in various decorations and symbols the official colors of the institute and its significance in science and engineering. On the front of the rostrum was the great bronze seal of Technology, while directly behind the speakers' stand stood a high, semicircular architectural screen flanked on either side by pillars of dignified simplicity in keeping with the design of the institute buildings. On this screen, inscribed in letters of gold, were the names of the past presidents of Technology—William Barton Rogers, the founder, and Runkle, Walker, Crafts, Pritchett, Noyes, Maclaurin, Nichols, Thomson and Stratton.

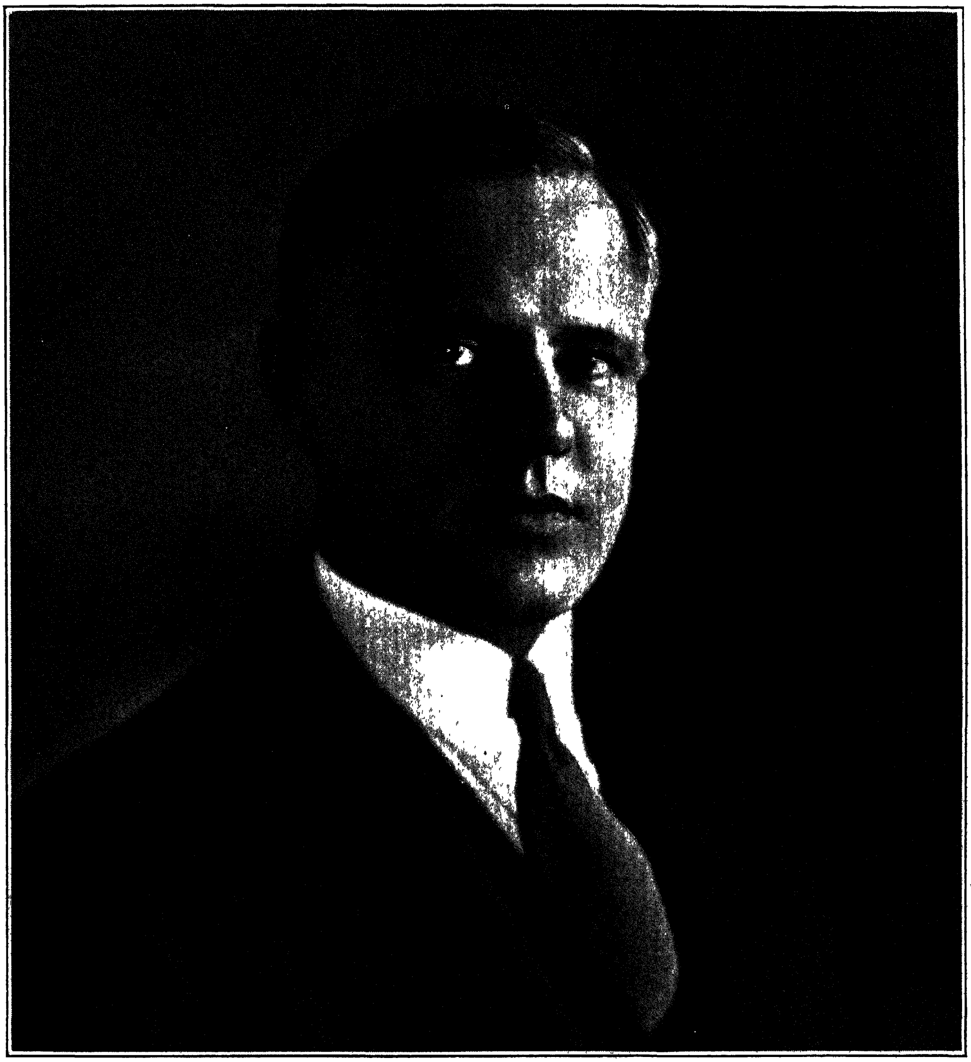
At three o'clock Chief Marshal Macomber opened the ceremony by introducing Rev. Dr. Sherrill who made the invocation. His voice was carried clearly to all parts of the audience by a public address system arranged by members of the department of electrical engineering. Dr. Stratton then made the opening address in which he spoke of the coming of Dr. Compton to Technology. Dr. Compton then delivered his inaugural address. President Hibben, of Princeton, where until recently Dr. Compton has been head of the department of physics, expressed the regret that every one at Princeton felt upon the departure of Dr. Compton, but congratulated him upon the opportunity for high achievement at Technology. Dr. Lowell, of Harvard, speaking, as he expressed it, as a near neighbor and a friend of Dr. Stratton, recalled the growth of Technology, and to Dr. Compton he said:

> We have met to welcome you to the title and duties of president of the Massachusetts Institute of Technology. Much have we heard of, greatly do we esteem, your contributions to physical science pure and applied; and now we look forward to your administration of a body founded for these aims. In your manifold labors you will be helped by the experience, the wisdom and the vast knowledge of Dr. Stratton, to me a near neighbor and a cherished friend.
>
> One who has seen a sapling grow to a mighty oak may almost doubt his recollections. For its fame and power Technology is not old among institutions of higher learning and in its early years obstacles of no common menace barred its path. Its charter was granted at



—*Ewing Galloway*

THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

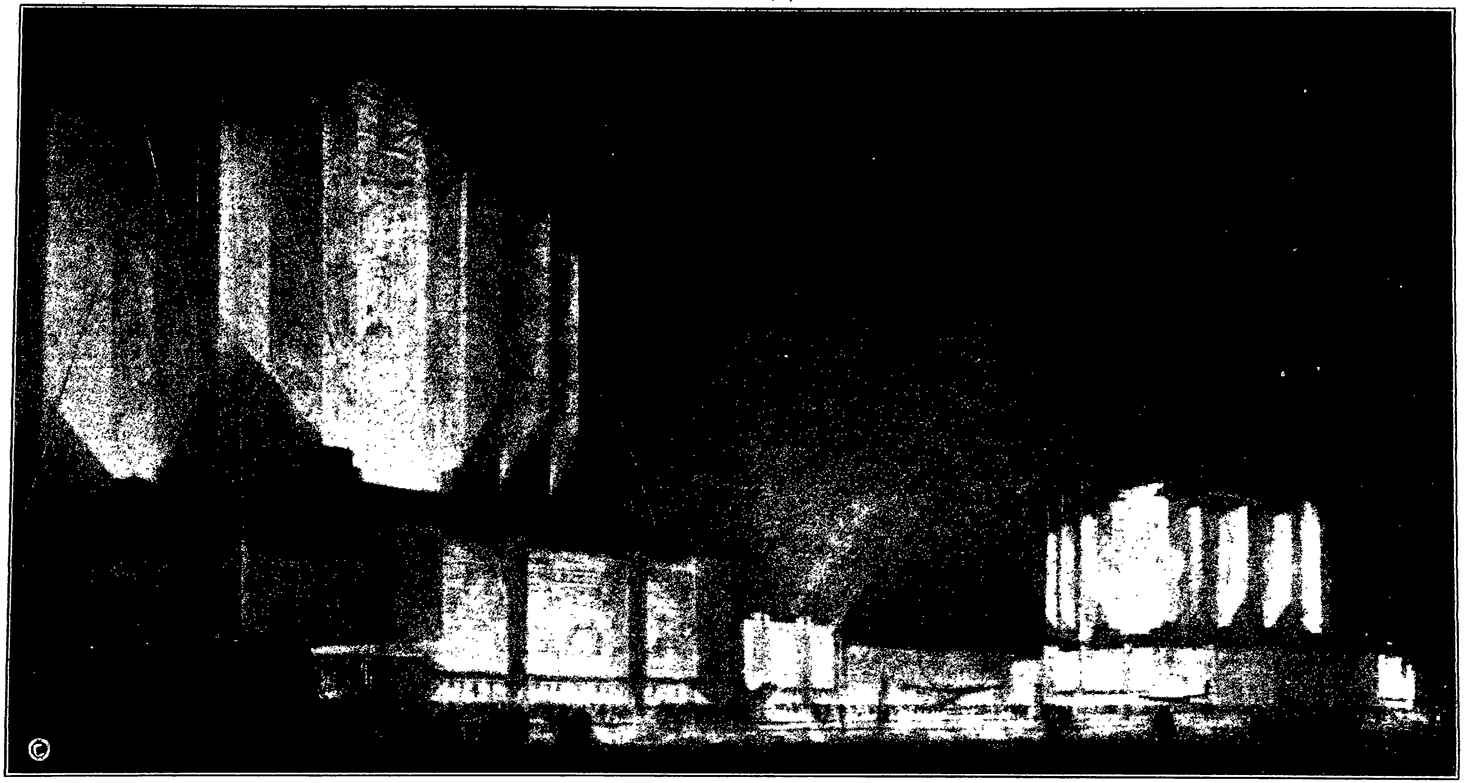


DR. KARL TAYLOR COMPTON

EMINENT INVESTIGATOR IN THE FIELD OF PHYSICS, WHO RELINQUISHES HIS POSITION AS CHAIRMAN OF THE DEPARTMENT OF PHYSICS AT PRINCETON UNIVERSITY TO ASSUME THE PRESIDENCY OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

the outbreak of the Civil War, when nothing could be done toward its active use. After the war its career began, in a small way at first, but with rapidly growing numbers. Yet in a few years it was nearly overwhelmed by an economic crisis, and that—a pioneer in education—it survived was due to the devotion of its faculty and the faith and courage of its projector and its corporation. Weathering the storm it entered on a new era of prosperity to become what we see here to-day.

Did I compare it to an oak? Excuse the inappropriate simile, for a tree has a limit to its size. After maturity it grows slowly, and although it may live long, adds little to its stature. Not so a school for research and to train young men. Its limits are measured only by its capacity for usefulness, its foresight and success in grasping opportunity. That the Massachusetts Institute of Technology will in the future, as in the past, render to the people in its field the service that they need we can not doubt. What demands the public may hereafter make we do not know, but we are sure they will be great, and in meeting them may your administration be memorable.



THE TRAVEL AND TRANSPORT BUILDING

A PHOTOGRAPH FROM THE ARCHITECTS' DRAWING. THE CONCEPTION FOR THIS WINDOWLESS METAL BUILDING HAS CULMINATED IN A MOST UNIQUE STRUCTURE, THE PROBLEM BEING TO OBTAIN A GREAT AREA WITH ITS INTERIOR FREE FROM COLUMNS AND OBSTRUCTIONS IN ORDER TO HOUSE THE GIGANTIC TRIUMPHS OF MODERN TRANSPORTATION WHICH WILL BE EXHIBITED DURING THE WORLD'S FAIR AT CHICAGO.

THE WORLD'S FAIR AT CHICAGO

SCIENCE as the symbol of human progress and the inspiration of industrial achievement will unloose her cloak of "mystery" and reproduce for the first time in history the whole drama of the "miracles" which began with the advent of the industrial revolution and which, in the present so-called mechanistic age, have given to mankind benefits beyond the fondest dreams of the savants of a hundred years ago.

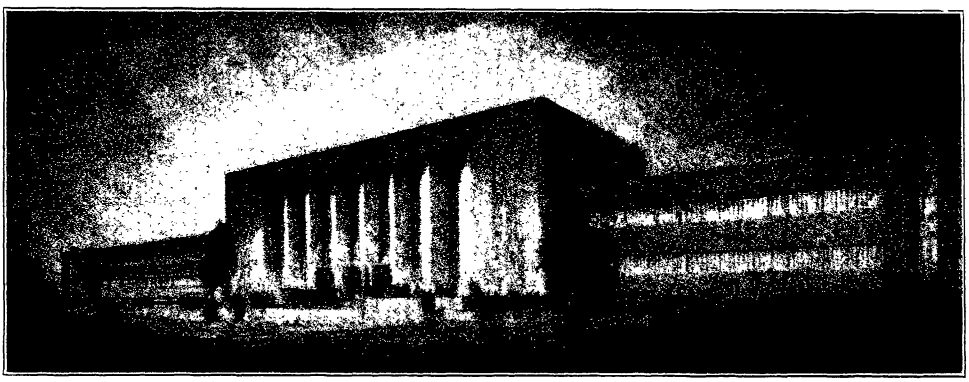
The scene of the drama will be the next Chicago World's Fair, scheduled to open in 1933, and the philosophy will be provided by the science advisory committee of the National Research Council which, at the request of the Chicago fair trustees, has already enlisted the volunteer services of more than four hundred of our ablest scientists, engineers and mathematicians for the presentation.

Just what pattern this new exposition philosophy will be given has not yet finally been determined, but it will illustrate man's highest achievements in the interpretation of the forces of nature and their adaptation to his every-day uses, in a dynamic and spectacular manner. It is not proposed by the men who have given this problem their unselfish attention for the past eight months to sensationalize the advances made in the realm of science; it is hoped to dramatize them with the aid of the showman's devices so that the average visitor at the fair will go home with a broader conception of what the scientist is doing for mankind.

The outline of this dramatization, as it has been drawn at this stage of the science advisory committee's deliberations, contemplates the separation of the pure and applied sciences, the latter to be traced back to their pure science sources wherever possible. A central temple of science would house the pure science exhibits. It is planned to show here the transition from ignorance, superstition and tradition as existing in the period before the scientific method was generally accepted. In the realm of the pure sciences major discoveries will be represented by striking exhibits.

The applications of science will be presented in a series of industrial exhibits which show their dependence on some scientific phenomenon or law. It has been recommended by the science advisory committee that the applied sciences be divided into three groups—physical, biological and the so-called earth sciences.

The contributions of pure and applied science, as they will be presented



THE ADMINISTRATION BUILDING

A PHOTOGRAPH FROM THE ARCHITECTS' DRAWING.

at the Chicago fair, will be a dominating note of the entire exposition. Through a cooperative effort of the national scientific societies and the American industries it is planned to show how, from a few single discoveries in pure science through the creative imagination of practically minded men, these scientific principles were applied for the betterment and increasing comfort of the human race.

Against the alleged evils that have attended the mechanization of industry, bringing mass production and power machinery to do manual work, it is planned to show how science is solving the problem of readjustment and how higher standards of living are now attainable as a result of this progress.

To me the scientific discoveries which connect the world of knowledge—acquired for its own sake—with the world of man's daily existence are like the connecting links of an intricate chain network. From one side radiate chains, long and short, simple and complex—frequently cross-connected but all extending into the region where the forging of each link had back of it the motive of increasing the sum of human knowledge.

From the other side stretch out other chains, also long and short, simple and complex, and likewise frequently cross-connected, but all extending into the region where the forging of each link had back of it the motive of some practical application or the gain to be derived from adding to the world's tools.

The investigations on the conduction of electricity through gases, the production of electrons and the structure of matter are the links forming a chain leading to telephone service, the whole radio art and a host of other useful things. On the other hand, a study of every industry shows chains which lead far back to the original discoveries in pure science.

The cross-connecting links unite the chain of any one particular industry with the neighboring one, forming a network of whole modern industrial structure. So extensive are the interrelationships between our industries that alternating times of repression or prosperity pass over practically all of them at the same time. If each industry went its course independently of the others, such a condition could hardly occur.

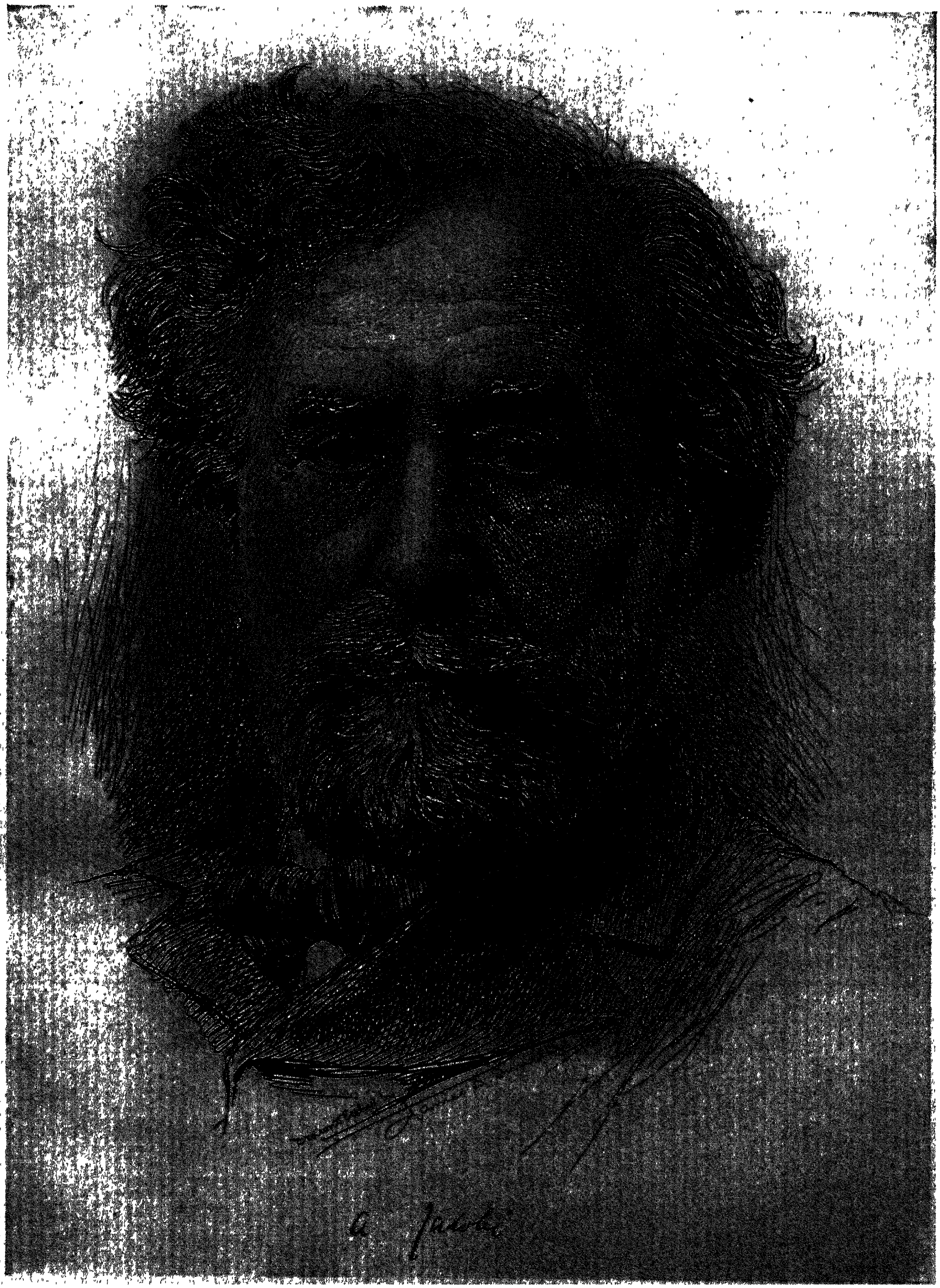
The spirit of cooperation will prevail in the temple of science. But supplementary to this spirit of cooperation there exists also among the industries the spirit of competition.

It is our wish to create an exposition philosophy that will be quite different from anything ever undertaken before. It will have running through it a thread of uniformity in the manner of presentation and in the objective of that presentation which has never heretofore been present in any large exposition.

MAURICE HOLLAND

THE CENTENARY OF ABRAHAM JACOBI

IT seems only the other day that a medical meeting was incomplete without Dr. Jacobi in the chair; his vivid personality is so contemporaneous that at first it is difficult to realize his centenary. Even the "younger men in the profession" remember so well that low voice with the interesting accent which often made us lean forward in our seats, those deep-set and penetrating eyes, the bronzed face, the splendid head and magnificent shock of hair crowning the small, trim figure, that we need a chronology to remind us he was cradled a century ago. It was long our habit to group him with his friends Osler and Welch, with whom he was frequently associated on committees and campaigns, and yet he was old enough to be the father of either, and was in fact the teacher of the latter. In his long life, Jacobi knew Valentine Mott — the



pioneer surgeon who came into the world several years before Washington was inaugurated president of the new nation—and he likewise knew many internes who are now rounding out their first decade of practice.

Abraham Jacobi was born before the Schleiden-Schwann cell-theory, the discovery of anesthesia, the clinical triumphs of the great men of Guy's, the introduction of experimental medicine by Claude Bernard; he was middle-aged before the birth of antisepsis and bacteriology; he was old before von Behring treated diphtheria with antitoxin and Jacques Loeb explained the theory of tropisms; yet he was modern enough to hear that the Soviet government had established an Institute of Experimental Endocrinology at Moscow, and that the new generation of Russians had founded a Pediatric Society at Odessa.

Metternichism in 1848 closed the careers of myriads of promising youths, and Jacobi, for his participation in this European revolution, was transferred from the clinics to a Prussian dungeon—for two precious years the ink faded uselessly on his recent diploma. Then escape, through a friendly jailer's intercession, and the three-master *Trimountain* carried the exile to a foreign shore. Forty years later the Prussian government invited the fugitive to return—as professor of pediatrics in the University of Berlin, but too many ties bound "the last of the forty-eighters" to the new motherland. Jacobi had become an integral part of American life, and like Jacob Henle, who had tasted the same brand of Prussian justice, he declined the honor.

Jacobi was one of the forces that made the nineteenth century the "century of the child." Not only was he our first teacher of pediatrics both in the lecture room and at the bedside, not only was he the guardian at the nation's nursery door, not only were his monographs the guide posts of his colleagues, but he made us remember the soul of the child. It is infinitely pathetic to recall that Jacobi's own first-born died in infancy, and at the age of seven his beloved Ernst passed away. Joseph O'Dwyer was a savior of childhood, but four of his sons died young. Thousands of little patients were saved by Jacobi, thousands of mothers blessed his name, but the father of pediatrics in America could not save his own children. A generation later, visitors to Lake George would hear Jacobi speaking of his lost boy. There stands in the writer's library a set of Jacobi's early reprints, collected and arranged by himself, bound and saved for his boy. On the first page is written in Abraham Jacobi's characteristic hand—*Für meinen Ernst gesammelt.* A terrible line—mute testimony of the impotence of the art of medicine.

In these days of ever-multiplying biographies, it is a strange neglect that the present writer's "Life of A. Jacobi" remains the only biography of this benefactor of the human race. His life was unique in many ways, and out of the thousands who knew him, there are those who should pause and give us recollections. Let us hope that the centenary of his birth will stimulate a disciple to preserve for posterity the record of the man who taught the medical profession the importance of the child. The science of medicine will make technical advances such as he never knew, but a nobler physician than Abraham Jacobi will never stand at a child's bedside. His lifelong battle for pure milk certainly deserves a volume. To this biographer we leave this sentiment: The father of pediatrics in America—he brought the cradle into medicine; he taught a nation how to feed its infants; and childhood is safer because of the life work of Abraham Jacobi.

VICTOR ROBINSON

THE SCIENTIFIC MONTHLY

AUGUST, 1930

PSYCHOLOGICAL HYPOTHESES CONCERNING THE FUNCTIONS OF THE BRAIN

By Professor KNIGHT DUNLAP

THE JOHNS HOPKINS UNIVERSITY

SINCE the fifteenth century, the philosophers who have discussed the human mind have based their theories on two concepts, namely, the soul and brain. With the rise of physiology in the nineteenth century, the brain assumed still greater importance, and the phrenological conceptions of Gall and Spurzheim led to conceptions of localization of mental functions in the brain which seemed to give that organ a detailed importance in place of the general importance it had held. One has merely to go back to the writings of the philosophers and physiologists and psychiatrists from 1850 to 1900 to recognize the positiveness with which psychical processes were assigned to the operation of brain cells. The proponents of interaction couched their arguments quite frankly in terms of certain hypothetical items of "consciousness" which they called sensations, images and feelings, and which were claimed to be products of cerebral action. The parallelists, on the other hand, objected not so much to this notion as to the converse notion that consciousness in some way acted causally upon the brain cells. It is metaphorically easy to see how a brain cell by its action might secrete consciousness as a rose sheds attar or a harp string music. That a "sensation" or an "idea" could have energy to excite or modify the "material" action of a cortical cell seemed to these allegorists to be a less plausible supposition. Yet the parallelists accepted the cerebral processes as the only bodily processes with which this consciousness was directly connected, even if the connection was denied to be a causal one.

Even as late as 1925 an American neurologist who occasionally breaks into popular philosophizing expressed himself as follows:

> We do not know exactly how a sense organ is excited, how a nerve fiber conducts, how a muscle contracts, how a gland secretes, or how the brain thinks, although we have satisfactory evidence that all of these organs do perform the functions mentioned. No biologist with all the evidence before him can fail to make this deduction. Why some other people accept the evidence in all of the cases except the last and refuse to do so in that is hard to understand. Presumably it is due to lack of knowledge of the biological evidence or else to a mind fortified against this evidence by prejudice.

When experimental psychology began to develop, in the latter half of the nineteenth century, the soul was slated for rough treatment, and all but a fraction of one per cent. of psychologists since that period have refused to involve the soul in their problems or their methods or their conclusions. This revolt against the soul was in no sense a philosophical or a religious movement, but a purely scientific insurgence. The term soul has literally no precise meaning, because it has a plurality of different meanings

which are utterly confused by the persons who use the term; and science can not proceed by the use of meaningless terms and jumbled concepts.

If you consider only a few of the concepts of the past and present, you find them a motley aggregation. You find the psyche, or unindividualized life force; the ghost or shade; the indweller; the double or "other one" (the Ka of the Egyptians, which seems really to have been the placenta); the ego; the "personality," and such ilk. You will find these concepts startlingly different from one another, and you will not be willing to affirm or deny the existence of the soul until it has been made precisely clear what it is that you are affirming or denying. You will also find that the perennially engrossing question of immortality is a vastly different question according as it is tied up with this, that or the other kind of soul, and that millions of people have believed in immortality while denying the existence of any sort of soul.

With the putting of the soul out of psychology, a vacancy was created into which a series of substitutes have crept. The case is somewhat like the one presented in the parable of the devil which was cast out of a man, but which shortly returned, bringing a number of other devils with him. "Consciousness," which as its form indicates is an abstract term, became for the soulless psychology a concrete noun, designating a kind of thing, or observable something, which was made the basis of the mind, as the soul had formerly been. There is a pernicious tendency on the part of man to seek to explain phenomena by pointing to an assumed substantial something behind or under it, as the Hindus sought to explain the foundation of the earth by assuming an accommodating elephant on whose back it rested. Even to-day, when the term consciousness has, through the efforts of modern psychologists, been restored to its abstract meaning, there are small groups of fundamentalists who still speak of consciousness as though it were objective and observable, and a greater company of biologists and physiologists who believe it to be a kind of quasi-objective reality.

The soul is a hard customer: in spite of our excommunication it is difficult to keep it permanently outside the fold. Like the repressed desire of the Freudians, it is constantly sneaking back, disguised under some other name. One might suppose that "intelligence," after the thorough confusion wrought upon it by philosophers and biologists, and "intelligence tests," would be harmless terms, obviously abstract and tentative. The discussions of the question whether intelligence is one or many, if you attend to the actual significance of these discussions, should disillusion you. Intelligence, in some of its conspicuous usages, is just our old friend the soul again, merely divested of its thaumaturgic and vitalistic draperies and wearing statistical false whiskers.

We have with us also the good old soul masquerading in a cloak of many colors under the alias of personality. Some of those who revere intelligence revere the personality also; but in general, those who worship at the shrine of the latter ignore or slight the altar of the former. In spite of the fact that the more experimental of the psychologists use the term personality strictly to describe the impression which the individual makes on others, there is unmistakably a group who, dissatisfied with our dealing with the individual's perception, thought, feeling, actions and habits, insist on dealing with these all over again from the point of view of "personality traits"; and who obviously deem that in so doing they are getting closer to the vital core of the individual's mental life—to his soul, in other words.

Even with consciousness, an intelli-

gence or a personality as a substitute, the passing of the more robust concepts of the soul from psychology threw a greater emphasis on the brain, and experimental psychologists, following the lead of the physiologists, sought to find the secret of the mind in the chemical operation of the cerebrum, and stated their problem and results indifferently in factual terms of actual occurrences of perception and thinking and feeling, or in terms of hypothetical brain states and cerebral processes, or more frequently, indeed, mingled the two terminologies in a kind of scientific hash.

We accepted the conventional sensory centers in their phrenological signification, and solemnly sought for thought centers and feeling centers and for other centers corresponding to more recondite classifications of mental facts and occurrence. Within the year, a European physiologist has achieved notoriety, at least in America, by announcing the discovery of the sleep center. The obvious mental defects of those who have suffered from pathological brain development and from brain disease and trauma have fitted into the brain-center scheme in a general way, and have been made to fit more specifically in fearful and wonderful ways, much as Neolithic man fitted his corpses to cramped burial bowls. With the emphasis on mental heredity, it was early assumed that this heredity was determined by the type of brain inherited. If musical talent "runs in a family," then a "musical brain" must be hereditary in the family stock.

The experimental method, however, became too vital a part of psychology to permit the long continuance of this situation. All this schematization eventually appeared to be what it really was, namely, an elaborate interpretation of preciously slight experimental fact. The work of Sherrington had opened new vistas of possibilities. The psychologists were restless and ready for migration to pastures more promising than the phrenological, as soon as a practicable route should be opened. In America, this pioneer work was done by Shepherd Ivory Franz, whose experiments on the recovery of vision in monkeys in which the visual centers had been permanently put out of operation, and in the reeducation of tabetics, showed the way.

Since that time, of course, there have been those who have gone to the opposite extreme in interpretation of experimental results. Little has been added with certainty to the indications Franz was able to outline, although there has been some hazardous drawing of specific conclusions not justified by the data.

Justifiably or unjustifiably, the psychologists' conception of the function of the brain has changed, and this change is the most significant single reformation in the history of the science. The new formulation of the psychologists seems also to have affected the workers in the biological sciences. Even the eminent neurologist whom I quoted a moment ago now puts his theories in a quite different style, much more in accord with psychology.

In brief, the new working hypothesis in regard to the brain can be reduced to a series of statements.

(1) The brain is an integrating organ, and we know of no other functions which it has.

(2) The brain "centers" are anatomical, and not psychological.

(3) There are no known differences in the kind of function between cells in different parts of the brain. (There may be differences in the time-relations, energy and stimulation of these actions.)

(4) There are no known types of function possessed by cells in the cortex which are not possessed by peripheral neurons, although there are types of functions possessed by certain peripheral neurons (the selective stimulability of receptors) that are not possessed by central neurons.

(5) Consciousness is an abstract characterization, not of brain cells, or even of the brain as a whole, but of response, that is to say, reaction. Put concretely, certain responses are conscious. The brain actions, taken by themselves, are neither conscious nor unconscious.

(6) "Conscious" is merely a descriptive adjective applied by convention to such responses as hearing, seeing, thinking, etc. These processes are so named by common consent, and the naming is in no wise an explanation. No one, not even among the former behaviorists, denies the occurrence of seeing, and of a variety of processes which seem properly classified therewith; and the calling of these conscious is a mere matter of useful convention, like calling certain mechanical actions explosive. Any other term would do as well, if generally employed.

The best simile I know to express the relation of the brain to response, consciousness and unconsciousness is the simile of the telephone exchange system. The brain is a system of central stations, connected with one another by trunk lines and connected each with a multitude of subscriber's stations by afferent and efferent neurons. So long as the lines are intact and the central stations in normal condition, any subscriber can call any other subscriber in the city. Here the simile breaks down, because in the telephone system, the subscribers who are called can call back over the same lines (*central volens*), whereas the connections from receptor to effectors in the animal body are one-way lines. The receptor can call, but can not be called except over a different line. The telephone system is, in a way, more efficient.

In another way, and a very important way, the nervous system "has it over" the telephone system, since from a single receptor a multitude of effectors can be innervated at once, and conversely, a multitude of receptors can cooperate in the calling of the same effector.

This brings us to the really important integrative feature of neural action. Within certain limits, the nervous system acts as a whole in conscious response. Here our analogy breaks down completely. In describing a sample reaction we speak conveniently of the stimulus as if it were the action on a few receptors, and the response as if it involved only a relatively few afferent, cerebral and efferent neurons and a few muscles. But we know that the real stimulus is a pattern involving practically all the receptors in the body; and the real response involves the nervous system integratively, and practically all the muscles, and many, at least, of the glands. Even such a response as the knee-jerk in the uninjured animal can readily be shown to be no mere reflex but to depend on a vastly greater assemblage of receptors than those terminating in the patellar tendon, and I am confident that within two years we shall be able to show that all the muscles in the skeletal system participate in this so-called reflex, and in all other overt responses of the human body.

In this integrative system, the visual cortex is "visual" only because it happens to be directly connected with the retina. Normally, no visual stimulus can affect the organism, in more than a limited local way, unless the connection between the retina of the eye and the skeletal muscular system be intact; and perhaps the smooth muscular and the glandular systems are important. Experimentally, the connection can be broken in any one of four ways: (1) By destroying the retina; (2) by cutting the optic nerve; (3) by cutting the optic tract; (4) by isolating the occipital cortex from the remainder of the brain.[1] In each case the result is the same. The animal is blind. Theoretically, the same result would be obtained by cutting all the efferent fibers running from the brain to the muscles and glands, but this experiment can not be

[1] This was Franz's method.

tried, and I strongly suspect that it would not succeed unless the cerebellar connections were cut also. Seeing requires a functioning and variable connection between the retina and the muscular system. If, however, after destruction of the occipital cortex, the retina can be functionally connected to some other part of the cortex, vision will again occur, although perhaps not as efficiently as before. An analogous condition is again found in our telephone system, where, if your exchange is destroyed by fire, the cables are cut over to another exchange, and your phone is again alive, although the crowding of the new exchange may interfere somewhat with efficiency of operation.

Although recently published conclusions maintain that in the rat, the destruction of the occipital cortex does not materially decrease the efficiency of visual discrimination of a crude sort after sufficient time has been allowed for recovery from the operation, the data which are offered do not seem to support the conclusions. Nor, in fact, are the data so far sufficiently critical to support any definite conclusion. But even if certain responses analogous to tropisms or simple reflexes do occur after the recovery from operation, we must not expect to find the more delicate performances resulting from the same sensory type of initiation as efficient as they are when the brain connections are normal. On this point, as on the other points of interest in animals who have recovered from brain operations, much carefully and accurately controlled experimental work needs to be done before conclusions can be drawn. In addition, histological methods must be applied, so that we may know what has really happened in the brain of the animal in the process of recovery from the operation. Professor Pike has trenchantly stated these requirements in his recent note in *Science.*

The function of nerve cells, inside or outside of the brain (always excepting the receptors), can apparently be reduced to a single category, so far as present knowledge is concerned, namely, to be irritated, or excited, and to discharge and so irritate other cells. Differences in thresholds of irritability, differences in energy of discharge, differences in the temporal features of discharge—these there may be, and there are differences of spatial interconnection to be reckoned with; but other differences we wot not of.

The negative factors in this scheme are drawn from neural anatomy. The positive factors are the result of our increasing knowledge of discriminatory perception, by which it has been made apparent that a difference in perception, a perceiving of this as distinguished from that, depends primarily upon the building of a difference in muscular response.

One can not discriminate between two objects, or between two situations, unless one can make a reaction to the one which is different from the reaction to the other, and can make these reactions in such a systematic way that the presence of the one object or situation evokes the one response, and the presence of the other object or situation evokes the other response. These responses may be of a general or of a specific type. They may be, for example, movements of avoidance and approach, or they may be vocal movements, producing spoken words. The specific response is the more scientifically useful, and the vast vocabulary of words at our disposal together with the constant necessity of inventing new technical terms as new discriminations are required are living testimonials to the basal characteristic of discrimination.

From this situation there results a consideration which at first appears to complicate the problem, although it may

explain certain operative results which seem otherwise to offer difficulty. We know that perception is a matter of habit formation. The regularity and consistency of stimulus patterns builds up, through successive responses, types of response which are perceptions of specific objects. Stratton's experiments with inverted vision show that it makes no difference whether the image on the retina is erect or inverted, provided it is consistently one way or the other for a sufficiently long (really a surprisingly brief) period. Other laboratory experiments with prisms described by Sanford give results of the same order. It is to be assumed, therefore, that if regular stimulation of a certain brain area by nerve current from the retina, and the retina only, builds up the responses which become perceptions of light and color, a sudden change in stimulation by which these cortical cells are stimulated from sources other than the retina may produce a somewhat similar afferent and muscle pattern, and so evoke perception of the visual mode, without visual stimulation. This would perhaps be a temporary effect, and may explain the results which have been reported from the experiment of stimulating the cortex directly by electric currents. However, I should wish these experiments repeated under careful psychological control before leaning heavily upon them.

The explanation of imagination of visual, auditory or other modes, where there is no effective receptorial stimulation, does not offer difficulty. Such evidence as we have tends to show that in having a visual image the observer makes a response which terminates in a muscle pattern which has habitually followed a stimulus pattern of the type he is imagining. For example, in imagining any specially definite object, Totten has shown that the observer makes eye movements of an appropriate type. Perhaps many other muscles are employed, and experiments now in contemplation will eventually supply evidence on this point. It is not necessary to assume that the visual cortex is excited in visual imagining, or that the auditory cortex is excited in the production of auditory imagery. Nor need the destruction of the normal visual or auditory "centers" permanently deprive the animal of visual or auditory imagery, even if the eye does not resume its function.

We are approaching at this point a most important problem, namely, the extent to which actual muscular activity is necessarily involved in conscious responses. I have certain notions about this, but some acute experimenters are at work on the muscular problem, and it will be advisable to await their results. There are a host of fascinating problems connected with this one, but if I am to get to my main point within reasonable limits of the reader's time I must resist their fascinations and pass on.

The nineteenth century emphasis on the brain as the source of mental life naturally tended to identify individual differences in mentality with differences in the constitution of the brain. The man of superior mental ability may well be supposed to have a better brain, and the low-grade moron may reasonably be assumed to have a low-grade brain. The expert mathematician has a mathematical brain, and the clever writer a literary brain. Most of us have just common, mediocre brains.

A short time ago, an ambitious young psychologist seemed to have demonstrated that with superiority and inferiority of mentality went superiority and inferiority of the spinal reflexes; superiority and inferiority, at least, in respect to speed of action. Measurements of the time of the knee-jerk in groups of people ranging from moron to highly intelligent, when correlated with intelligence-test scores of the same

persons, gave coefficients of correlation of significant size. "Mentally quick, speedy kick," was the indication. Most psychologists were skeptical, as the details of the experimental report were not clearly satisfactory, but the conclusions were nevertheless heralded as one of the greatest discoveries of the age. Unfortunately, the skeptics' expectations have been confirmed, and it is informally reported that more careful experiments show only a chance correlation, and the brain's aristocratic position is so far unshaken, although there is no reason to suppose that high speed of reaction is a uniform characteristic of either spinal or cerebral efficiency.

The relation of brain structure and organization to mental ability receives confirmation from pathological and surgical observations. Loss of a considerable portion of the cortical substance, except from the frontal region, profoundly affects the mental characteristics of the patient, even though no specific sensory alteration be produced. Degeneration of tissue likewise produces mental degeneration. Microcephalic and hydrocephalic individuals have impaired mentality.

For the greater range of individuals, however, from medium-grade morons to geniuses, no characteristic differences in cortical tissues are discernible. Here, the difference may still exist, and there may be characteristic differences in the brains of mathematicians and prize-fighters, bankers, politicians and priests, in spite of the fact that research has not yet shown them.

For the low-grade moron, however, examination does seem to show a structural peculiarity, consisting in a deficiency of interconnection of the cortical cells. This is a fact of profound importance which fits squarely into our integration theory, and also into the heresy I shall propound in a few minutes.

The general hypothesis that mental differences of capacity involve corresponding differences in brain constitution or organization may then rest unchallenged for the present. All lines of evidence converge towards the confirmation of the hypothesis. We can not escape the conclusion that where two responses differ, there is difference not merely in receptor action, and effector action, but in brain action also. Where systems of response differ in characteristic ways, there must be characteristic differences in brain action, no matter what these differences are due to. This, by the way, is one of the reasons why we may confidently expect that any readjustment of brain following operative injury will show its effects in some way in the response.

Brains differ, and the important question is: How do the brains get that way? For the discussion of this problem we may reasonably ignore the obviously pathological brains; those which have lost substance, have suffered syphilitic or other degeneration, those whose arteries are hardened and those demonstrably badly constructed from birth.

It is fairly certain that the important differences in brains of the normal range, including the brains of most geniuses, morons, criminals, saints and *hoi polloi* generally, are differences in organization, histological or chemical in character, and not anatomical in the gross sense. It is true that since Gall and Spurzheim many earnest investigators have thought to have discovered anatomical cerebral characteristics corresponding to mental traits, but these discoveries do not seem to stand the test of time and scientific investigation, but like the bumps of the phrenologist and the facial and other character-signs of Lombroso, Blackford and Company vanish into thin air.

There have been those who have thought the total size or weight of the brain was indicative of mental caliber. This thought was especially comforting

to the males, when it was pointed out that the average weight of the male brain is greater than the average weight of the female brain. Perhaps the emphasis on the fact that, relative to the body weight, the female brain is the heavier has largely contributed to the elimination of the brain weight hypothesis, although there are still anatomists of high scientific standing who think there is something in it. Possibly there may be; but there are so many other unanalyzed factors involved in the cases put forward that the psychologists are justified in their skepticism.

Others have studied the convolutions of brains, and have thought to find in their conformation or relative development the indications of mentality. These theories, again, may have something in them—it is almost impossible to prove a negative—but the probability is too small to cause us serious concern. That the cephalic indexes, once deemed so important by the anthropologists, have a significance in this connection is no longer seriously maintained.

How, then, does the individual human brain get its differential characteristics? A number of alternative answers might be suggested. First, we might say, the differences are inherited. The mathematician's brain has a peculiar organization which is inherited from ancestors whose brains had the same characteristic, and the moronic brain is likewise a heritage from moronic ancestors. A decade or two ago, in the vogue of a sort of heredity of almost fatal character, this view was held with an extremeness which seems incredible to us now. I believe that the biologists were primarily responsible; but anyhow, the psychologist went so far as to assume that education, and the environmental influences generally, had almost nothing to do with the organization of the brain. The moron might, through special training, learn to use his poor brain a little more effectively than he otherwise could, but its moronic character was supposed to be established by a simple process of growth from the originally incompetent germ-cells. And so on, for the total range of differential characteristics. Heredity, however, to-day, is not what it used to be, and perhaps it never was. We no longer set heredity over against environment, nature against nurture, instinct against habit; but we conceive each in terms of the other. In this reformation, the psychologists have been with the leaders of the procession.

The second extreme answer to our question is the hypothesis that (still considering only the non-pathological brain) the differential characteristics are due entirely to education or training. This answer is not in good form to-day. The majority of psychologists, and of biologists also, I think, incline to take a compromise position, holding that training is influential in determining the organization of the brain, but that heredity establishes the limits.

This is nearer the truth, but still implies a false conception of both heredity and environmental influence. A sounder form of statement, for which I received sharp criticism a few years ago but which I think agrees with Jennings' formulation and which is rapidly gaining ground, is to say that nature and nurture are mutually inclusive. Hereditary tendencies are not absolute, but are relative to the environment, and are capable of formulation only in terms of the environment. Environmental influences, on the other hand, operate only on hereditary tendencies. Each is a function of the other, the two being comparable to mathematical factors in a product, which accordingly varies with both and becomes zero when either factor becomes zero.

This formulation, however, leads to the consideration of a possible case which is most interesting. If either factor in a product has a constant value of unity, then all variations in the

product are determined by the variations in the other factor. At this point, therefore, I wish to introduce a hypothesis which, from a point of view of the unanimous conservatism heretofore obtaining on the point, is nothing less than rank heresy.

As regards mental characteristics and capabilities, I should maintain the conventional point of view, as expressed in the most modern formulations which I have just outlined. These characteristics vary on account of differences in heredity and differences in environment. But as regards the brain, I shall claim that the actual differences in normal individuals are due to differences in training alone; in other words, the direct hereditary factor has, for practical purposes, the constant value of unity.

This hypothesis is the logical consequence of that which is more and more becoming the working hypothesis of psychology, namely, that the brain is not the sole or even the primary "organ" of the mind, but is a contingent and subservient part of the mechanism.

I am insisting, in short, that so far as the brain itself is concerned, one brain is equal to any other brain for purposes of training; and that, although different brains are, at a given time, different, so far as practical organization is concerned the difference is due to differences in the actions of the brains' environments.

Let me distinctly state, however, that this commits me to no behavioristic position. I do not say that it is possible to train any individual to the point of mental and bodily capacity to which it is possible to train some other individual; I do not say that one individual is equal to any other individual for purposes of training. I am speaking so far solely of brains. To say that you can take any child, however young, and make a mathematician or a musician or a poet or a mechanic of him by any practical method is against the present evidence and is a proposition not to be seriously considered.

To say that the feeble-minded individual might have been trained to be a normally intelligent person is equally absurd, unless you extend the term training to include such operations as the fundamental modification of metabolism and the administration of glandular extracts. Ordinarily, we do not include these under training. But if you do so extend the term, then the statement is not quite so absurd.

The training of the individual is primarily the training of his brain. Other tissue can be trained to a certain extent, but the brain is the trainable organ *par excellence.* This holds for brains in school, in the shop, in the gymnasium and in business.

Training processes originate in the environment. But between the environment and the brain there are mechanisms which must not be overlooked. These mechanisms include the receptors, the glands of inner secretion and the muscles. The muscles are responsive to the environment through the brain, but their activity in turn stimulates the brain anew. We may not subscribe to any of the various specific theories as to endocrine action, but we must admit that the responses to receptorial action are modified by certain of the hormones, and the secretion of these hormones is in turn controlled by responses. Hence training, whether we speak of the individual as a whole, or of the brain alone, is carried on primarily through response. The response theory on which psychology to-day is solidly grounded irresistibly pushes us to the conclusion that the response tendencies are modified mainly by responses, and training of any sort is a modification of response tendencies.

The brain can be trained by the environment only in so far as the peripheral mechanism is capable of mediating the

training. If the practical limitations of training are not set by the brain itself, they are necessarily set by these peripheral mechanisms.

The premises so far are merely corollaries of the present working hypothesis of psychology. There is, however, an implicit assumption which must be made explicit, and this assumption is perhaps the only new feature of my radical position. It is the assumption that every normal brain possesses, in infancy, potentialities in excess of the development in actual life, even in excess of the development of the brain of the best individual.

There are doubtless individual differences in these potentialities, but they are so far outside of the range of development that they do not practically matter. To illustrate the point. The brain of every non-pathological individual is early capable of being developed, in mathematical capacity, beyond the capacity of the brain of the most brilliant mathematician; but few have the peripheral mechanism capable of administering the training. The brain of the low-grade moron was, in its early stages of development, perfectly capable of developing into a brain equal to that of the highest genius; but the peripheral mechanism was defective. If I may again resort to a crude analogy, the situation is like that of a multitude of motor cars with gas tanks of capacity ranging from nine to thirty gallons. But if the purses of the drivers are limited to the purchase of from two quarts to three gallons of gas, the differing potential capacities are practically of no importance.

I do not claim that there are different initial capacities of development of normal brains. I claim merely that if there are such differences, they are of no practical consequence for actual possibilities of development.

This assumption is not a wild one. There are many curious facts which suggest it, of which I shall mention only one here: the fact that in every brain there is an excess of neurons over those actually brought into functional operation. While number of brain cells is not perhaps the most important determinant of brain potentiality, it is undoubtedly of some importance.

If I am not mistaken in my diagnoses, psychology is very definitely on the road towards the consideration of the brain as an essentially plastic organ, especially in infancy and early youth, capable of meeting any demands which the receptors, the muscles and the glands are able to make upon it systematically. The development of muscular systems in the past seems to have depended upon the requirements of adaptation to environment, and the development of receptorial types seems to have depended upon a very definite requirement, namely, the existence of two sorts of stimulus, definitely related and grounded in the same spacial points or units. The failure to develop receptors for radio waves, for example, seems to have been due to no limitations of human brains, but to have depended upon the fact that these radiations, although they must have been present to the organism from the beginning, have not been systematically related, in the physical scheme, to any other forces playing upon the organism. There have therefore been no ways in which these radiations could be interrupted and made useful to the animal.

Functionally, the brain seems to be an integrative or interconnecting organ, and nothing more, except that its integration is habitual. More specifically, the brain by its multiplicity of synaptic connection enables any receptor to stimulate any muscular and glandular element. Its integrative action has then four features: (1) It enables the same stimulus-pattern at different times to produce different results; (2) it enables

different stimulus-patterns at different times to produce the same result; (3) it tends to fix the same result to the same pattern, and (4) it tends to develop fixed difference of result from differences of pattern which are practically important. Perception and emotion or feeling fit into the scheme perfectly. Thinking seems to offer some difficulty. In perception, the stimulus pattern produces a response which has become mechanized. In thinking, the presence of sensory stimulations as essential initiatory factors is not yet demonstrated. We are here offered two alternatives: (1) the implicit muscle pattern theory, which assumes that in every thought process there is an actual muscle pattern, the end result of a preceding response; and that this muscle pattern, although it may not be demonstrable by ordinary means, is nevertheless effective as a stimulus. (2) The muscle substitute theory, which, while admitting the importance of the muscle pattern in general, claims that the muscle pattern in many cases drops out entirely, and the afferent impulse is supplied by a correlated mechanism which has been trained to produce the same brain pattern (and therefore the same terminal muscle pattern) which has been produced by the former muscle pattern. This substitute mechanism can be no other than the cerebellum, and hence I conceive of a train of thought, of a habitual sort, as essentially a series of discharges between the cerebellum and the cerebrum. Decision on this point rests upon the completion of much work, including the galvanometric work on the detection of faint action currents of the muscles, upon which Dr. Max has been engaged for several years.

It is to be emphasized that if this view is correct the brain supplies no initiative in our responses, conscious or otherwise. It supplies merely connections and conservation, *i. e.,* habit. The brain has no product called consciousness; at least, we know of no such product. Consciousness is an abstraction; consequently, we can't reasonably ask what it is or where it is located. The term conscious is purely a descriptive term applied to the processes of perception, feeling and thinking. Conscious means nothing but the common peculiarity of these processes. Our question then is really: Where is perception (or thought or feeling), and what produces it? In the case of perception, our answer is definite. Perception is produced by the cooperative action of receptors, afferent and efferent neurons, brain cells and in many cases muscle cells. Perception is this total response, and hence it is located where the response is, namely all along the line, from beginning to end. Feeling could be as specifically localized, except that, unfortunately, we use the term freely in a double way: to designate the stimulus pattern, and also the response it initiates. Thus in popular language, hunger, pain and joy are feelings; but we speak also of feeling hunger, feeling pain and feeling joy. In the first sense, the feeling is the stimulus pattern to the visceral and somatic receptors, and is, spatially, in the soma and viscera. In the second sense, the feeling as a process of response is all along the line, from the stimulated tips of the receptors to and including the resultant action pattern.

Although I claim that any brain (aside from injury, degeneration and nutritional conditions) is in its infancy capable of development to the point of function possessed by even the best brains, I must admit that there are individual differences in capacity. Some persons simply can not be trained to the height of skill which others show, in music, in mathematics, in general intelligence. This statement of course is not absolute, but merely means that these persons can not be trained by the same

procedure as that by which others are trained, and perhaps by no procedure now possible. There is, theoretically, an environment in which the child of unmixed feebleminded stock may develop into a person of high intelligence, just as there is theoretically an environment in which the child of pure blue-eyed ancestry might develop brown eyes, but these environments may be incapable of actual installation without killing the individual.

If we grant individual differences in capacity under practicable environmental conditions, and yet claim that these differences are not inherent in the brain, we are forced to the only alternative, namely, that they are due to the periphery, that is to say, receptors, muscles and glands. There is nothing startlingly new in the ascription to the periphery of importance for mental development. The only novelty lies in the emphasis on which I insist. We have long known that blindness and deafness are definite obstacles to normal development of the mind. In the usual type of environment, the deaf child is very greatly retarded in mental development, although the results may not be of practical importance under the usual circumstances of civilized life. From an observation of anosmic individuals, I am convinced that their mental processes are even more different from those of normal persons than are those of the color-blind, especially in their emotional lives and the manifold factors dependent on the emotional responses.

These, however, are relatively minor determinants. The glandular and general metabolic characteristics I suspect of being major determinants. The muscular system, however, must not be underestimated. The muscles are not merely immediate agents in adaptation to environment: they furnish a continuous component in the stimulus pattern, and hence a constant factor in training. Not enough attention has been paid, heretofore, to the characteristic muscular development of different races. Even in the case of the true Negro, where the striking characteristics, aside from color and hair texture (which are probably negligible) and glandular peculiarities (which are not negligible), are in the length and form of leg and in the leg musculature, comparative studies of motor abilities have been made on the hand and arm action, but not on leg and foot performance.

Even height and weight are not to be ignored. Small men show traits which are different, on the average, from those of tall men, and the stature of the African pygmies is certainly not without its effect on their mental attitudes. The effects of stoutness and fatness on civilized mentalities may be complex in their production, but they are none the less real.

As for the differences in the chemistry of different individuals, and in the function of such peripheral mechanisms as the muscle plate in its relation to the muscle, where slight variations would be capable of producing large results, we have not even scratched the surface of the problems. The investigation of these peripheral factors I believe to constitute the most pressing problems of psychology.

Let me now illustrate my heretical theory more objectively. Suppose that a group of English babies from Lancashire were exchanged at birth with a group of babies from a Negro tribe such as the Wolof, or a similar fairly homogeneous breed. Suppose that the changelings were, in both cases, brought up by their foster parents with no prejudice on account of color or details of form and feature, and suppose them to be treated by neighbors, tribesmen and townsmen in the same impartial way, and to be exposed to the same training, the same education, the same social in-

fluences, as their foster brothers, and to eat the same types of food and wear the same types of clothing as their associates. In other words, suppose the babies from Africa to be brought up as nearly like English babies as their own constitutions would permit, and suppose the babies from England to be brought up as nearly like Africans as possible. What would be the result? We have enough data from actual transplantation of breeds to enable us to predict a large part.

We can be certain that the adopted children will be modified in many particulars towards the types of the foster breed. The babies from Africa will, when they grow up, differ from the English less than Africans brought up in Africa differ from English. They will speak English; they will have English interests, attitudes and manners; and in their thinking processes they will be somewhat, at least, like the English.

On the other hand, we know that in certain characteristics they will still be little, if any, modified from the type of the original breed. They will still be black; their hair will still be woolly, their lips thick, their legs long and their sweat glands peculiar. In almost all anatomical respects, and in some physiological respects, they are still Africans.

Apparently, then, we have two contrasting sets of personality traits. On the one hand, the physical, not affected by the environment, but determined entirely by heredity; on the other hand, the mental, very markedly determined by the environment, relatively little by heredity.

This statement would have been acceptable a decade or two ago, but to-day its very form carries its denial with it. To say that certain traits are determined by heredity and others determined by environment is to speak in terms of a mythical heredity and a mythical environment which have gone the way of the gods of Greece. We know of no differences in the force of heredity or the effectiveness of environment from one characteristic to another, physical or mental.

These principles stand out in modern theories of development.

First: every characteristic or trait or modification is as much a product of environment as is any other. In no case therefore can the effect of heredity be said to be greater or less than the effect of environment; and *vice versa*.

Second: differences in absolute measurements of traits dependent on differences in environment may be said to be great or small in relation to the environmental differences only in terms of the importance ascribed to the differences at the time; and this importance is a highly changeable matter. For example, a change of one per cent. in the shade of the skin (that is, in the coefficient of light absorption) may be said to be small, and a change from savage habits of eating and deportment to English manners may be called large. But this means that the one difference is such as happens at the moment to be of no great interest to us, while the other happens to affect our attitudes. Really, the two differences are incommensurable. Even if we should compare a difference of 5 per cent. in skin shade with a difference of 5 per cent. in length of leg, the two differences are still incommensurable and our practical evaluation on one as compared with the other is still subject to reversal as situations change.

Third: although we may admit a theoretically possible equivalence of environments, so that the effect of a certain environmental pattern may be the same as the effect of a certain different pattern, we expect actual equivalence to be attained very seldom. The same holds *mutatis mutandis* for hereditary patterns. We expect, therefore, in general, a difference in development where the

environment differs, and a difference in development where heredity differs. The resultant differences, however, may be great or small in respect to the units of measurement employed, and they may be important or unimportant from the pragmatic point of view.

All this bears on our expectation of results in the baby-swapping game. It is not probable that the skin color, the hair texture and form, the skeletal proportions and structures or any other physical characteristics are actually unaffected by the food, climate, types of activity enjoined and the other environmental influences in infancy and youth. Variations in these features may be practically negligible in the case of our swapped babies, but we can not assume that they are not present. On the other hand, in the traits which are said to be greatly modified by the environment—speech, manners and the mental processes generally—we have no warrant for supposing that our swapped babies become actually of the type of their foster folds, although in certain features the differences may be negligible.

In other words, our Africans have a certain inherited endowment, which is nothing fixed or absolute but which is merely the potentiality of developing in another, more or less different, way in another environment. The English environment has, in general, an effect which differs in an important way from the African. It shows strikingly in the mental traits. On the other hand, the Africans and the English have different potentialities of development in the same environment. It shows strikingly in the physical traits. But we have as yet no reason to suppose that both the results of differences of environmental effect and the results of difference of endowment do not apply throughout the total range. Our adopted babies from Africa will not be English, either physically or mentally, and our adopted babies from England will not be Africans, either physically or mentally.

Now let us take another supposition. Suppose that instead of swapping babies we could merely swap brains. We would have African babies with English brains brought up in the normal African way, and English babies with African brains brought up in the normal English way. Of course this is a little more drastic supposition than our first one, for we have at present no way of performing the operation; but the supposition is nevertheless useful. What would be the result of the brain interchange?

In accordance with the theory I have advanced, there would be no effect whatsoever, so far as the development, behavior and mentality of the individuals are concerned. The English babies with Wolof brains would develop into Englishmen indistinguishable, by any measurements, from ordinary Englishmen of the same type and environments. Wolofs with English brains would become thoroughly ordinary Wolofs. There is just one exception to be made. The transplanted brains, after maturity, might still retain, for theoretical absolute analyses, something of their original characteristics, if there really are any essential differences between Wolof and English brains in their early embryonic stages. But these hypothetical, vestigial differences would be devoid of consequences in any other parts of the organism or in the actual functioning of the brains themselves.

These inferences are based on the assumption of brain transfer at a very early age. I am not attempting to speculate as to the limiting age in the embryo or fetus. If now we should consider the effects of transplantation at a late age, the results would be very different.

The brain of an adult Wolof, if miraculously transplanted into the skull of an Englishman, would not serve the

Englishman at all adequately. Neither would the Englishman's brain serve the Wolof. The two brains have received radically different training and have undergone different development, and are hence differentiated in ways which very probably can not then be reversed. To what extent the adult brain could be retrained I am not able to guess. There is warrant, however, for the belief that the years of infancy and childhood are the years during which the foundations are laid for all further training.

It will be understood, of course, that the transplantations I am describing are put forward merely for the purpose of sharply outlined illustrations. Although it is by no means impossible that such transplantation might be made in the embryonic stages, nothing in my hypothesis depends on the possibility of such an operation.

Theorization of the sort involved in the hypothesis of brain superpotentiality may seem, at first glance, a futile form of amusement. I do not think it is. Quite aside from the physiology of the brain, the modern progress in psychology has been from dependence on assumed central factors determining mental development towards more intensive search for peripheral determinants. In this statement I am obliged to use two terms implying physiological reference. That is because our habits of making such reference are solidly fixed. The distinction can be stated in other words, but not so sharply. There is no doubt but that our purely psychological data and the view-point to which they have led us imply a cerebral theory such as I have outlined. For the critical evaluation of our psychology, it is necessary to recognize this clearly. We have left behind us, in America, the psychological constructions of Wundt, Titchener and Thorndike. Most text-books of psychology still talk of stimulus and response in archaic fashion, as if a spot of light falling upon the retina were the total stimulus resulting in an action limited to the contraction of the triceps muscles. But most text-books of psychology are epitomes of discarded theories and exploded facts, and the primary work with graduate students is to purge them of the rubbish they have learned in elementary courses.

For nearly a generation, the facts of integration have been recognized. We know that human animals respond, not to limited stimulus applications, but to patterns. We know that the important characteristics of the stimulus patterns are both spatial and temporal. While it is over-generalization to say that all the receptors participate in every reaction, that is the actual limit. Illustrations of the pattern characteristic are too simple and omnipresent to justify dwelling on them. Likewise, it is an over-generalization to say that all effectors participate in every response, but it is not much of an over-generalization.

The fact that patterns are the real stimuli has been recognized in certain special cases for centuries. It is emphatically indicated in Stratton's classic experiment to which I referred above. But this fact was not brought forward as a basic fact in all experiences until the last generation. For this delay two things were responsible. First, the survival of the doctrine of sensation: mental elements out of which whole perceptions were supposed to be compounded, and from copies of which, properly fitted together, ideas were formed. William James started the revolt in America against this synthetic doctrine, but the weight of two schools of psychology, clinging to established formulations, has kept many simple followers to the old faiths.

The difficulty of fitting the integration or pattern facts to the old brain theories was another strong deterrent to prog-

ress. Stimulus patterns as units of stimulation and action patterns as units of action require neural patterns as units intermediate between stimulus and action. This refuses to fit the old theory. Moreover, although sensory qualities may be analyzed out of the objects of perception, and localizing something called sensation in the brain may serve as a temporarily satisfying physiological scheme for them, relations are just as real analytic results in our perceived world, and where in the brain are their psychic substitutes to be localized?

The development of perception is clearly a matter of progressive integration, in which the responses are due to various stimulus patterns in which the entire substitution of visual for auditory, auditory for tactual and so on is permissible. Under the spell of the localization theory, this was forced into a childlike play-scheme of the aggregation of sensations and images, in which images were changed into sensations and *vice versa* as the explanation demanded. This could not last. The obvious need for psychology is to discover, recognize and formulate the laws and principles of perception, thinking and feeling. If the facts do not fit the theories of brain physiology, then the theories must be remodeled to fit the facts.

In Germany, the same process is under way, somewhat belatedly. Gestalt theory is a belated recognition of principles which have been accepted as matters of course by progressive American psychologists for twenty-five years. Like all belated movements, the Gestalt theory is very much confused, and suffers too at present from an exceptionally bad attack of *substantivitis:* the belief that when one has assigned to a group of phenomena a class name, like insight, one has thereby explained the phenomena—a disease by no means confined to Gestalt.

The Gestalt movement is without doubt helpful in stirring up the old bones, and even in America seems to be useful to the psychologists of the dissolving schools who had failed to take note of the progress seething just outside their scholastic walls. The modern views are in the way of universal adoption, and retrogressive movements such as behaviorism and psychoanalysis do not seem to have had any serious deterrent effect except in confusing the layman as to what is going on.

It is, however, just as important for brain physiology as for psychology to take stock of changing situations. There are two aspects of brain physiology: one, the chemical and electrical study of neural processes and their relations to the histological findings; the other, the interpretation of histological data in the light of psychological facts and theories. The first makes progress slowly, and the second constitutes 95 per cent. or more of what passes for brain physiology in text-books and lectures. The apparently rapid progress is most frequently into blind alleys, because the interpretations are based on outworn psychological theories or hastily assumed fact. Brain physiology, in the second or usual sense, is distinctly dependent upon psychology, hence the modern psychologist must actively interest himself in this field and not accept in simple faith the constructions based on the incomplete psychology of the past, or those of psychologically inexpert theorists of the present.

EARTHQUAKES, A CHALLENGE TO SCIENCE

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It is customary to think of the earthquake in terms of destruction and loss of life. The damage due to the earthquake is in some cases overshadowed by the damage due to fire which the earthquake has started and whose extinction is prevented by damage to the water system.

From the view-point of the seismologist the destruction caused by an earthquake is of secondary importance, whether it is the result of the shaking or of the fires. However, since the aim of science should be to benefit mankind and since the urge to scientific investigation comes in the first instance from the desire to reduce or prevent loss of life and property, it is proper to emphasize this feature of the earthquake problem.

In addition to the obvious possibilities of damage to cities and towns, there are a number of less obvious kinds of damage which have caused heavy loss in the United States in the past few years. These serve to illustrate the possible ramifications of earthquake investigation, now that most of the earth is either inhabited or put to the use of man.

One of these is the causing of landslides along railroad lines and highways through sparsely settled regions, a matter of importance on account of the large amount of mileage along the bottom or on the sides of steep slopes. This was best exemplified in the earthquake of June, 1925, which brought a great rock slide down on the tracks of the Chicago, Milwaukee and St. Paul Railroad in Montana (Fig. 1). This blocked a tunnel entrance for nearly a month and occasioned great expense for its removal. More serious loss was narrowly averted as one of the crack trains had pulled clear of the track covered by the slide less than a minute before.

The breaking of cables through submarine earthquakes has occurred in regions such as the Caribbean Sea, since cables were first laid. However, the only place in the North Atlantic Ocean where cable breaks from such causes might have been anticipated was the so-called Telegraph Plateau, a ridge in mid-Atlantic which extends almost from the Arctic to the Antarctic and where earthquakes have occurred and will probably continue to occur. However, seismologists were greatly surprised when on November 18 of last year there occurred a great earthquake in the vicinity of the Grand Banks of Newfoundland, which broke ten out of twenty-one cables crossing the area. Most of these were broken at more than one point, and while in a general way the principal breaks were within a circle about 125 miles in diameter which contains the epicenter of the earthquake, many of the breaks were far to the south. No adequate explanation of the wide-spread breaks is as yet available. They did not all occur at the time of the earthquake, but some of them were several hours later. The loss to the cable companies has been heavy in loss of tolls and in cost of repairs, which were exceptionally difficult in the winter season.

It is, of course, important to know whether or not the persistent reports of changes in sea bottom are correct. It is almost impossible to settle this question because of the inadequacy of earlier surveys. However, the vessels of the U. S. Coast Guard which are engaged in the International Ice Patrol are now taking acoustic soundings *en route* to

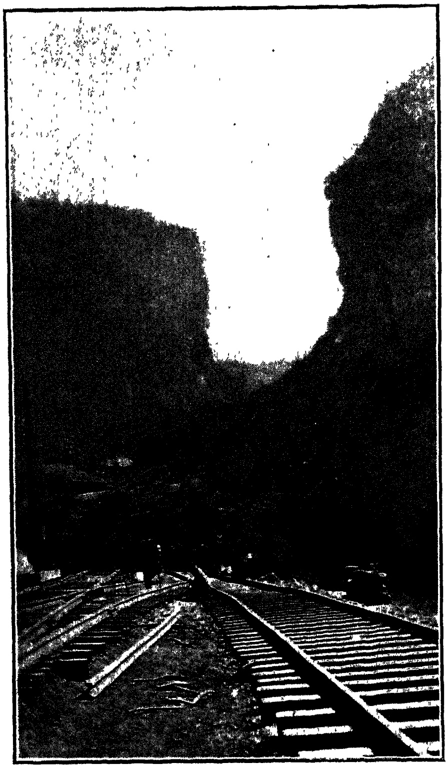


FIG. 1. ROCK SLIDE

DUE TO EARTHQUAKE, BLOCKING RAILROAD.

and from their sea stations to Nova Scotia, where they base during the iceberg season.

A rather rare event for North America was the destruction of life and property on the coast of Newfoundland by a tidal wave, which was most disastrous at Placentia Bay. There seems to have been an exceptional piling up of the wave owing to the peculiar form of the harbor entrance, since at Sable Island much nearer the place of the earthquake there was no report of a tidal wave. At most points in New England a heavy gale was raging and the seas made it impossible to distinguish earthquake effects. However, it was recorded on tide gauges on the outer coasts of New Jersey and Maryland (Fig. 2). It is interesting to note that the wave arrived earlier at more distant than at nearer points. Since the velocity of such a wave is fixed by the depth of water, it was possible to deduce a position for the origin of the wave which is not greatly different from the adopted epicenter of the earthquake.

Much the greater number of earthquakes occurring throughout the earth can be associated with mountain growth, remembering that many island groups simply represent the tops of submerged mountain chains, and also considering that the submerged ocean troughs which parallel mountain chains are in some way associated with them. Earthquakes of this type occur all around the rim of the Pacific Ocean and elsewhere.

There are, however, many earthquakes (and this is especially true in North America) which have no apparent connection with mountain building, and which have occurred in places where the surface geological conditions

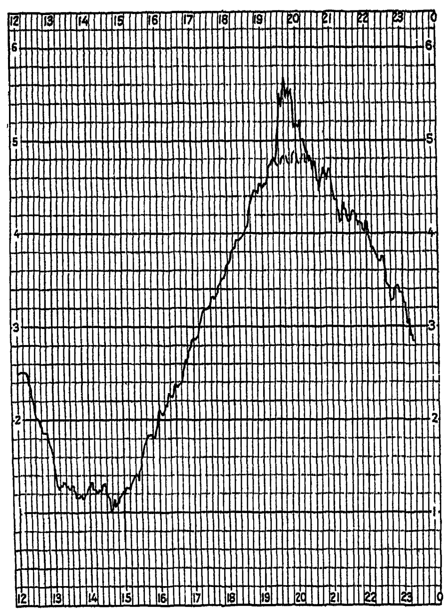


FIG. 2. TIDAL WAVE

FROM GRAND BANKS EARTHQUAKE OF NOVEMBER 18, 1929, RECORDED AT OCEAN CITY, MARYLAND. BROKEN LINE AT MAXIMUM INDICATES NORMAL TIDE.

give no clue to the reason for their occurrence.

One of the most interesting of these was the New Madrid earthquake of 1811, which centered near a place of that name on the banks of the Mississippi River in southeastern Missouri, which by itself was classed as one of the twenty greatest earthquakes in known history and which was followed by two other great shocks in 1812 which were almost of the same intensity, the activity continuing for nearly a year.

The shock was very severe and was felt sharply at Charleston, South Carolina, and Savannah, Georgia, but the feature of greatest importance was the formation of the so-called Sunken Country, or an area of 30,000 square miles which sank through five to fifteen feet, though limited areas throughout the region were raised a similar amount above the previous level. One of the results was the formation of Reelfoot Lake in Tennessee and changes in the drainage system of the St. Francis River. While the country was very sparsely settled and there were few people to report the changes, there is evidence of various sorts, as the drowning of cypress trees, to establish the principal facts. Earthquakes have been felt in this region probably every year from that time to this, and in several of the more severe shocks moderate changes in level over limited areas are reported to have occurred.

Equally difficult to explain is the earthquake at Charleston, South Carolina, in August, 1886. There were no changes of level, but the intensity was shown by the twisting of rails and the formation of sand craterlets. The principal interest in this earthquake from the view-point of the seismologist is that it occurred at all.

A relatively unimportant earthquake but one of considerable interest was that which occurred in the Panhandle of Texas in July, 1925. Here, again, inspection of the surface gave little indication of any reason for an earthquake, but drillings for oil brought out the fact that the region is the site of a buried mountain with steep slopes, a formation more likely to be associated with earthquakes than a flat or rolling plain.

It has been stated that submarine earthquakes are frequently associated with deep troughs. An excellent example is the trough paralleling the west coast of Mexico and Central America which was located and developed in 1924 by the steamer *Guide* of the Coast and Geodetic Survey by acoustic soundings (Fig. 3). With the development of interest in this subject which shortly afterwards resulted in assignment by law of seismological observations on the part of the government to that bureau, a special effort was made to find to what extent known earthquakes were located in this trough. A number were found, and since that time there have been earthquakes every year, including considerable seismic activity.

These different types of earthquakes serve the purpose of illustration. Earthquakes present many challenges to science. Some of these have been met;

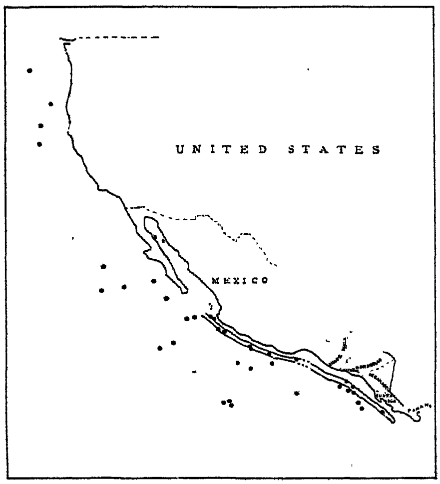


FIG. 3. SUBMARINE TROUGH AND ASSOCIATED EARTHQUAKES.

others have not been met at all, but in most cases the condition is intermediate between these extremes.

The first challenge is the cause of earthquakes. This is intimately related to the history of the earth, and if we had the complete answer we would have the key to much that is obscure in that history. For many years earthquakes and volcanoes were closely associated in the public mind. We now know that, while they are related, and all volcanic outbreaks are accompanied by earthquakes, all the greater earthquakes occur in regions remote from volcanoes or if in volcanic regions at a time when the volcanoes are not active. In the great Japanese earthquake of 1923 Fujiyama, an extinct volcano, was strongly shaken but was not roused to activity. On the other hand, the greatest eruption of Vesuvius in recent times was an explosive outburst near the same time as the California earthquake of April, 1906. This may have been a coincidence, but there may have been some relation, though if so it was more probably in the trigger force which timed the events than in the events themselves. It would seem that the volcano is a localized and rather superficial phenomenon as compared to the earthquake.

In general, earthquakes are due to slipping of two rock surfaces on one another, and it is peculiarly helpful to the study when this effect reaches to the surface. Examples of this are the California earthquake of 1906, where horizontal slipping reached as much as twenty-three feet; the Yakutat Bay, Alaska, earthquake of 1899, where vertical slipping was the greatest ever recorded on land in historic times, reaching a maximum of forty-eight feet; the 1929 earthquake in New Zealand with vertical slipping of twenty feet, and a number of Japanese earthquakes, notably the Mino-Owari earthquake of 1891, in which case the slipping was on a diagonal plane. I do not know whether we may assume that the amount of the slipping at the surface is the same as at the origin but there is certainly a very direct relation. The observed conditions in California led Harry Fielding Reid, of Johns Hopkins University, to propound his elastic rebound theory which is briefly as follows.

Let us assume that there is a plane of weakness and one side remains stationary while there is movement on the other. As soon as the strength of the rocks is exceeded there will be slipping. However, there is too much friction and irregularity to permit this being accomplished at once and there are a series of slips of irregular character which in turn send out the earthquake waves and account for their irregularity.

Now in order to study surface effects we must have accurate determination of the positions and elevations of fixed points in order to know the changes accompanying an earthquake and also to find out whether or not there is slow creep of crust between earthquakes. The Carnegie Institution of Washington, which through its advisory committee of seismology, Dr. Arthur L. Day, chairman, is the chief coordinating agency and strong financial supporter of the program of earthquake investigation in California, is convinced that this is a major part of the program. Accordingly through a special appropriation by Congress the Coast and Geodetic Survey has accomplished or will in the near future have accomplished the following things. It has executed precise triangulation in California and has in so far as possible connected it with earlier work, especially that done after the earthquake of 1906, so that it has the greatest possible value in determining changes; it has connected this work at three places with the more stable seismic regions to the east and in this connection has readjusted the triangulation of the western half of the country, using a method de-

veloped by Dr. William Bowie, chief of the division of geodesy, which reduces to a minimum the effect of the unavoidable errors on the final results; it has determined the position of a large number of monuments in a selected region so that the movements at different parts of the area can be studied. A similar program has been followed with regard to precise levels. The plan includes repetition of both classes of work at suitable intervals in order to record the changes.

No precise triangulation or leveling suitable to the purpose has been done in the New Madrid region. We know so little of the process which brought about the lowering of the surface over 30,000 square miles that we can not say definitely that it was the result of shaking down of loosely consolidated materials, though this is the generally accepted explanation. If this is adopted, is it likely that movements at the origin have any chance of being reproduced even approximately at the surface? These questions must remain unsettled until precise triangulation and leveling can be undertaken over this region. Owing to the great area involved, detailed investigation would be a major task. However, until this can be done an essential part of the fundamental data will be lacking.

It seems likely that we will have to get our information as to what occurs at the origin through the seismograph, and it is by no means certain that the possibilities in this direction have been exhausted. Frank Neumann, of the Coast and Geodetic Survey, has deduced the direction of the initial thrust from the records and has obtained the same azimuth from records of six stations in as many different directions from the epicenter. Also in the case of the California earthquake he obtained an azimuth almost that of the San Andreas Fault along which the slipping occurred. Perry Byerly, of the University of California, makes use of several phases and has deduced with even more detail the direction for the Chilean earthquake of slipping in a diagonal plane which agrees remarkably well with that deduced by Bailey Willis from inspection of this region.

An important problem in regard to which we have little satisfactory information is the course of events leading up to an earthquake. The statement is sometimes made that an earthquake occurred "out of a clear sky" without any previous activity in the region. My investigations in the preparation of an earthquake history of the United States a few years ago convinced me that this never occurs. In the case of the New Madrid earthquake, Indian tradition and other evidence support the view that there was another earthquake of perhaps comparable severity not more than one hundred years before. At Charleston, South Carolina, there was an earthquake in 1857, twenty-nine years before the great one. Records show that considerable activity preceded the California earthquake of 1906. However, it is still impossible to distinguish moderate earthquake activity from that resulting in a great shock. In the Imperial Valley there have been a long series of moderate earthquakes which have died away and at other times a much shorter series which resulted in an earthquake of great intensity. In February and March of this year there was an occurrence of this sort with considerable damage at Brawley.

It is, therefore, of great importance that the Seismological Laboratory of the Carnegie Institution of Washington and the California Institute of Technology at Pasadena is, with its subsidiary stations, locating all earthquakes and wherever possible associating them with the geological formations. Eventually this will lead to a definite history of the events leading up to an earthquake which, though it may not apply to other earth-

quakes, will at least throw light on the problem. A similar program is being developed in the San Francisco Bay region, through the universities located there and cooperators.

It has been stated that earthquake epicenters are being associated with geological formations. Since the seismometer is capable merely of measuring a time interval between the arrival of phases, it is necessary to assume the velocity of transmission, obtained partly from assumption as to place of origin and partly on the theory of transmission. If the path of the wave is chiefly far beneath the surface, the difficulty is less, since though there are changes in elasticity and density the conditions are much the same for all parts of the earth, so that the velocity will be much the same for the same distance between earthquake and recording station for any part of the earth.

However, when the station is within two hundred miles of the point of origin of the earthquake there are likely to be appreciable departures of the velocities from the average values because the waves pass through different geological formations and the velocity may differ with the direction. One method of attacking this problem is to measure the time of travel from large explosions, since in this case we know the point of origin accurately, and important earthquake wave theory has been developed and confirmed in this way. Earthquakes may be and are used, but it is always difficult to know the exact point of origin.

Seismic prospecting is a practical application of this method, though in this case we are associating changes in velocity or reflections with the geological formations for the purpose of identifying the latter and following them beneath the surface.

Permanent changes of the surface have been discussed. The Japanese have recently found that a definite tilting of the ground precedes by a few hours the occurrence of a strong earthquake, and by means of a tiltometer have proved such an occurrence for several earthquakes. There is no certainty that a similar effect would be observed in this country, since in Japan there appears to be a tilting of blocks, while such a formation either does not exist or is not a major factor in this country, but John R. Freeman has performed a real service by bringing one of the instruments from Japan and lending it to Stanford University in order to test the matter.

The principal earthquake waves as shown in Fig. 4 are P, S and L. P waves are longitudinal; that is, the vibration is in the direction of progress, and they take the path indicated between the earthquake and the recording station. The S waves are transverse; that is, vibrations are normal to the direction of progress, and the S wave follows the same path as the P but at a lower velocity. L waves travel along the surface. Many different waves result from reflection and refraction of P and S. The P and S phases and their reflections are seen in many seismograms, but for nearby earthquakes we often find two P's and two S's, a fact which must be explained. The first, that advanced by Mohorovicic, calls for a reflecting layer sixty kilometers below the surface which he called the continental layer because the observations demanded less thickness beneath most of the oceans and practically none beneath the Pacific. Harold Jeffreys (Fig. 5) has developed a theory which is in agreement with the probable wave transmission characteristics of the layers affected. He has layers of discontinuity at ten and thirty kilometers depth respectively with different physical conditions for each layer and for the region below the lower layer.

The next fact to be fitted into the pic-

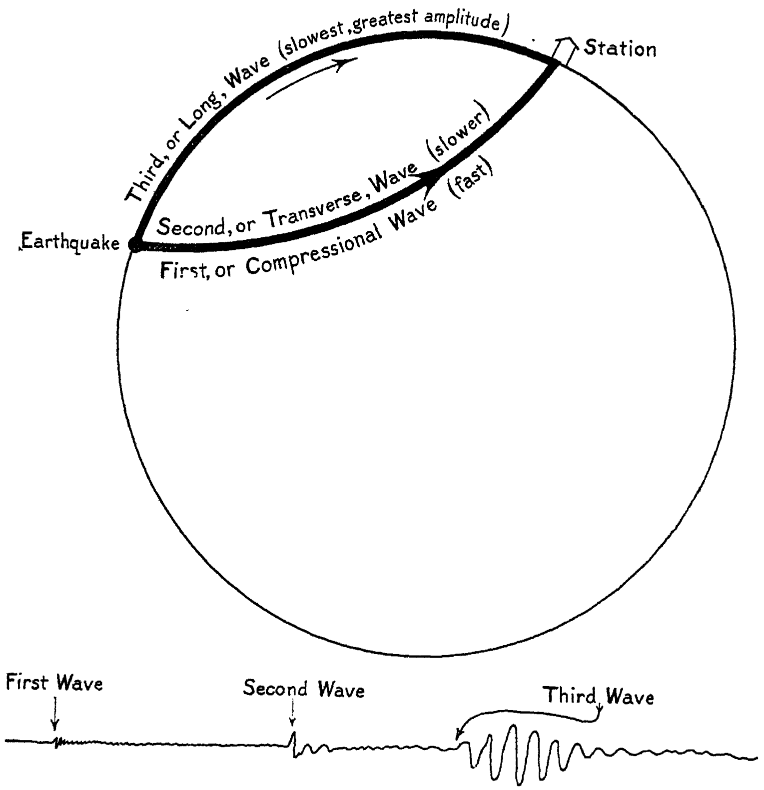


FIG. 4. DIFFERENCE IN TIMES OF ARRIVAL
OF FIRST AND SECOND WAVES GIVES DISTANCE FROM EARTHQUAKE TO STATION.

ture is that of isostatic compensation (Fig. 6). This requires that if the earth's crust were divided into columns one hundred miles square and about sixty miles in depth, they would weigh the same even if in one case one column had part of a mountain range at the surface and the other had its surface far beneath the sea. This conception is derived from study of precise gravity determinations and is the only one which makes it possible to fit together gravity observations made at different places. It is confirmed by determinations of average density. Now the fact of equilibrium is surprising in itself,

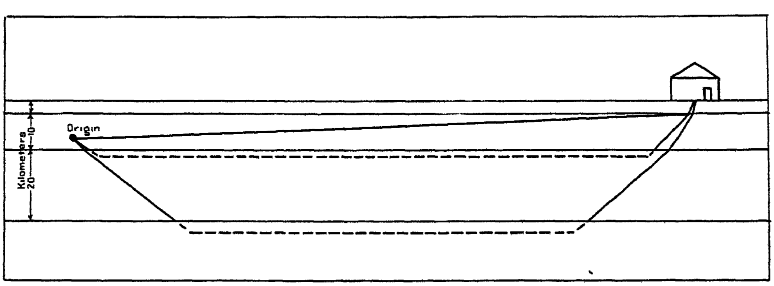


FIG. 5. PATHS OF PRELIMINARY EARTHQUAKE WAVES
THROUGH UPPER LAYERS OF EARTH'S CRUST, ACCORDING TO JEFFREYS.

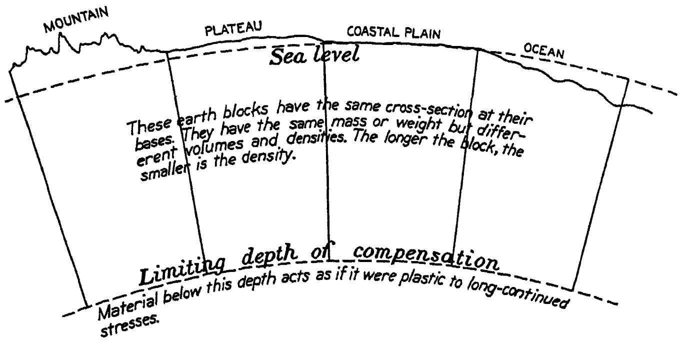


FIG. 6. SECTION OF EARTH'S CRUST
ILLUSTRATING THEORY OF ISOSTASY.

but it is still more so when we consider that it has been maintained in spite of a constant exchange from mountain to lower levels of vast amounts of material by erosion and sedimentation. This implies adjustment and, in general, this must go on mainly near the base of the column where the material is relatively plastic or will respond to long-continued stress without rupture. It is quite conceivable that stresses in the upper part of the column may build up and have to be relieved in such a way as to cause earthquakes. This is not set forth as a complete explanation of earthquakes, and all that we are justified in maintaining is that all earthquakes should have their origin above the depth of compensation. Occasionally it is held that one type of earthquake has a deeper origin, but for the vast majority it is certain that their depth is very much less.

In order to have any conception of earthquake causes, it is necessary to know at what depth they occur. Unfortunately the information is very defective, since only in some parts of Europe are conditions such that accurate determinations can be made. There must be a number of stations with suitable instruments within a few hundred miles of the earthquake; there must be instruments for recording the vertical component, and the time must be accurate to the tenth of a second. For a large number of European earthquakes the depth has been found to range from forty-five to sixty kilometers, though there undoubtedly are a very great many at less depth and some of the smaller ones may be very near the surface. I do not feel that there is as yet sufficient information on which to base a discussion of the place of earthquake origin in relation to the various layers that have been mentioned.

Now if the origin is at these considerable depths it is difficult to see how the so-called "trigger forces" act. However, it is practically certain that in the case of many earthquakes a state of unstable equilibrium continues for a long time until some sudden action of a very much smaller force than those which are involved in the earthquake itself brings about the occurrence. Such forces may be due to an exceptionally high tide on the coast or to the sudden melting of a large mass of snow but more generally to sudden change in barometric pressure. The great Japanese earthquake of 1923 was accompanied by a severe typhoon which may have fixed the time of its occurrence.

While we are considering the upper layers of the earth's crust there is another form of wave action which is important. The so-called long waves pass through the layers near the surface and

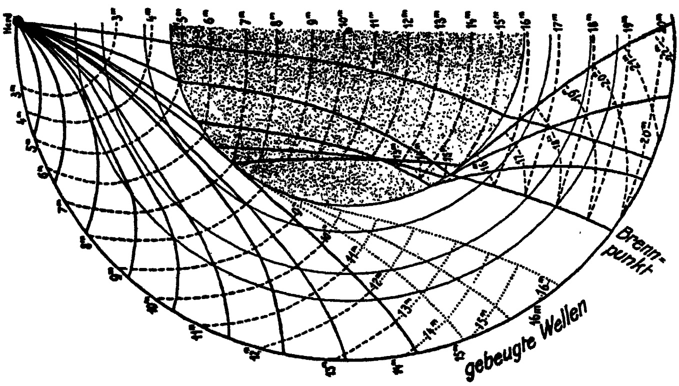


FIG. 7. EARTHQUAKE WAVE PATHS
THROUGH THE INTERIOR OF THE EARTH, ACCORDING TO GUTENBERG.

usually are of such long period that they extend sufficiently far below the surface so that local variations of geological conditions have little or no effect. Their velocity, however, responds to the average conditions of the layer through which they travel. It is, therefore, of interest to note that the waves speed up 18 to 20 per cent. beneath the Pacific Ocean as compared to continental paths, and this can be explained only on the assumption of greater elasticity which in the case of rock is associated with higher density. This confirms in a qualitative manner the conclusions drawn from the theory of isostasy. The question as to whether the other ocean beds have the same velocity as the Pacific or an intermediate value is not yet finally settled, though the proponents of the theory that the moon was derived from the Pacific basin and of the Wegener hypothesis of continental drift generally assume that the values are intermediate.

Now going deeper into the earth there is much to be learned from the behavior of seismic waves, but I will merely point out the evidence for the generally accepted view that the central portion of the earth is in a condition more rigid than steel and yet liquid in so far as transmission of waves is concerned (Fig. 7). The boundary is sharply defined and is about 2,900 kilometers beneath the surface. The discovery of the core was due to the sharp changes that take place both in the travel times of waves and in their characteristics when the point is reached, and passed, where the waves graze the core. The other evidence is that the recorded phases from distant earthquakes can be explained only on the assumption that transverse or S waves do not pass through the core. The situation is actually somewhat complex, as both P and S waves reach the boundary and each separates into P and S waves. Only the P waves pass through the core. When these P waves pass through the core and again reach the boundary each is broken up into P and S waves and may reach the surface in either form. The condition of the core is deduced in part from the velocities which must be adopted to fit the observed conditions.

In presenting this general picture it has been necessary to omit a number of subjects which are of interest chiefly to the seismologist. With the principal problems and accomplishments set forth the next thing is to see what are the specific problems in the United States and what is being done about them. The present is a particularly suitable time for such a review because it is little

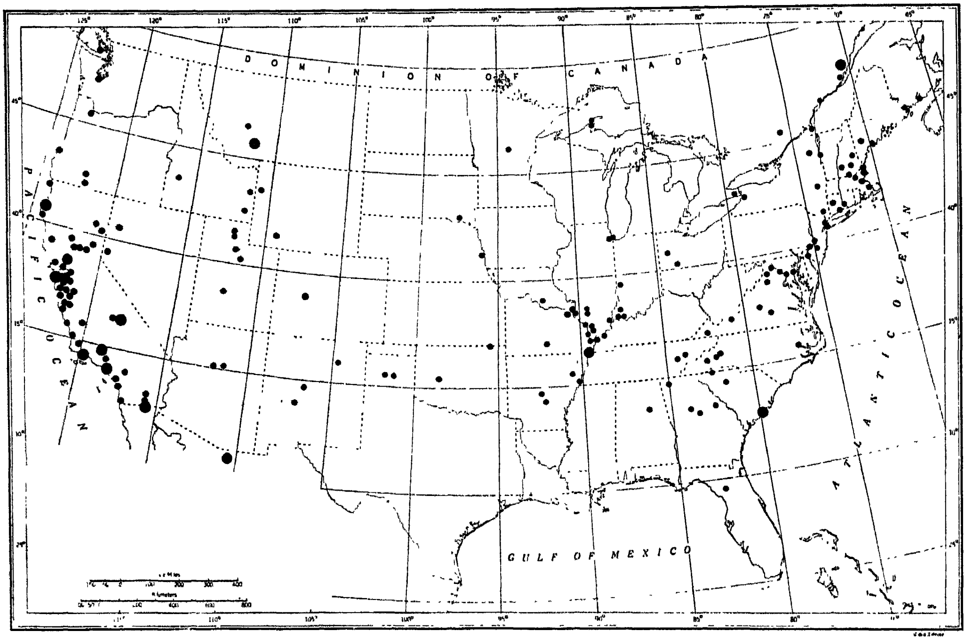


FIG. 8. KNOWN EARTHQUAKES OF THE UNITED STATES

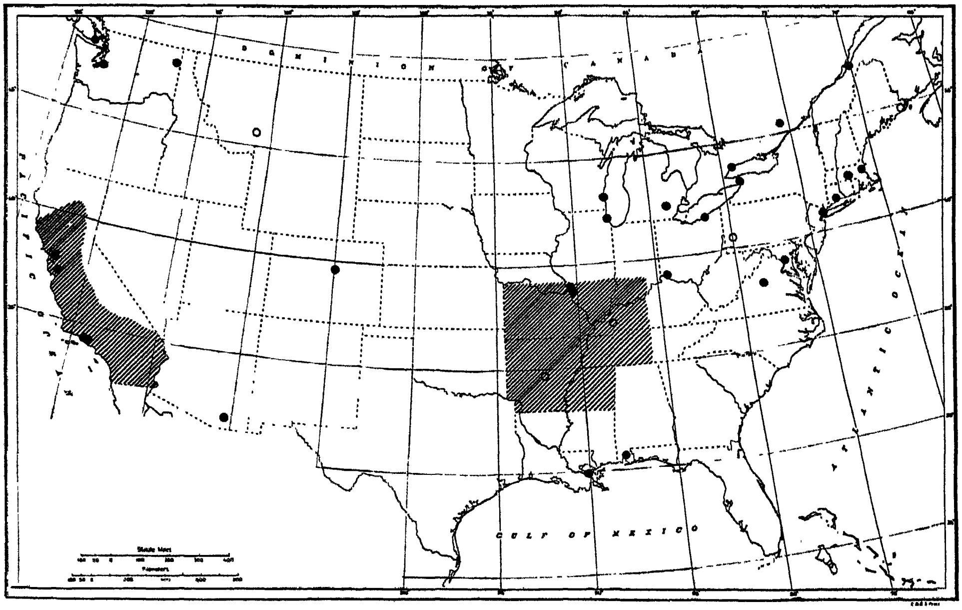


FIG. 9. SEISMOLOGICAL STATIONS

OF THE UNITED STATES AND ADJACENT CANADA. CROSS-HATCHING INDICATES AREAS OF SPECIAL INVESTIGATIONS OF SEISMIC REGIONS.

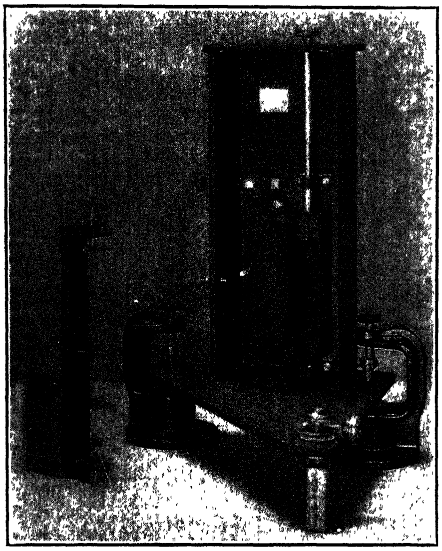


FIG. 10. WOOD-ANDERSON TORSION SEISMOMETER

more than five years since wide-spread interest and activity developed, and the next five years are going to be of great importance in establishing this work in its proper place.

The map (Fig. 8) shows the distribution of all earthquakes strong enough to be felt from the earliest times to the present. While principal activity is confined to definite regions, especially the New England region and adjacent Canada, the central region and the Pacific Coast region, there has been activity in nearly every state, and any institution which contemplates the installation of a station can be assured that sooner or later there will be recorded an earthquake at no great distance.

There are now or soon will be in the United States, including those new stations where the instruments are actually under construction and are recognized as first class, fourteen stations for recording earthquakes (Fig. 9). These are operated by the federal government, the universities and colleges belonging to the Jesuit Seismological Association and by other universities. There are other institutions where the instruments were installed some time ago and while useful are no longer considered first class. However, there are definite prospects of establishment of additional stations, particularly in the region where few or none now exist.

We no longer have to send to Europe for instruments to record earthquakes, though many fine types of instruments have been developed there. The first distinctly American seismometer was the Wood-Anderson (Fig. 10), developed in California. It is now unquestionably the best instrument for recording nearby earthquakes, and important contributions are to be expected from its records. This instrument responds to the extremely short period waves recorded by nearby earthquakes. Frank Wenner, of the U. S. Bureau of Standards, has developed another type of instrument better suited to the more distant earthquakes (Figs. 11 and 12). In this instrument the steady mass carries a coil; the motion of the support with regard to the coil causes it to move in a strong magnetic field, and the currents set up are recorded by means of a galvanometer. This general idea was developed by Prince Galitzin, of Russia, but the Wenner instrument has a considerable number of advantages. Another instrument is the McComb-Romberg, developed by H. E. McComb, of the Coast and Geodetic Survey, which includes a device modified from one developed by Arnold Romberg, of the University of Texas, for preventing effects of slow tilting of the

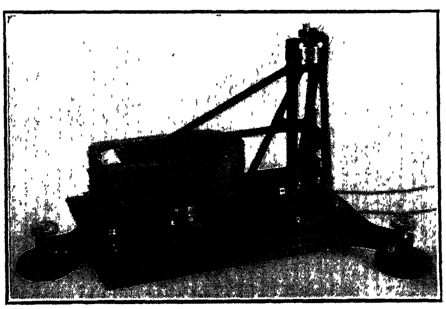


FIG. 11. WENNER SEISMOMETER

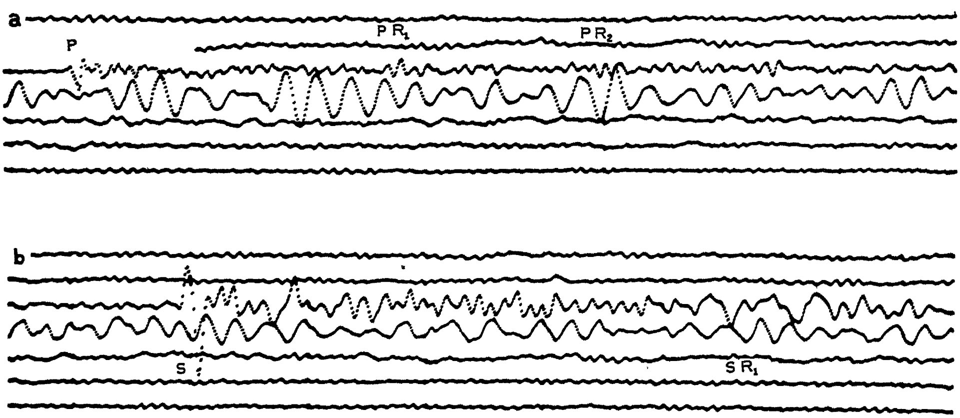


FIG. 12. RECORD PRODUCED BY WENNER SEISMOMETER

ground from affecting the records. This instrument, while a modern seismometer, has smaller magnification than those that have been described and is, therefore, well adapted to recording strong shocks and also to recording earthquake phases more clearly than sensitive instruments when microseisms are severe.

One justifiable European criticism of American stations is the lack of instruments for recording the vertical component. Since earthquakes are a three-dimensional phenomenon, recording in two dimensions is obviously incomplete. This is being rapidly remedied at many of the stations, especially at Jesuit institutions, and such installations will probably be made general within a few years.

The stations described are for the recording of distant earthquakes. There are important installations for recording of nearby earthquakes in southern California, in the San Francisco Bay region under auspices that have been mentioned and in the Mississippi Valley region under the auspices of St. Louis University and the National Research Council.

The interpretation of records is quite as important as securing them, and there are fewer persons who are expert in interpretation than in the securing of them. Interpretation with a large number of records available for examination is particularly useful. As yet the only places where such work is done are Washington, D. C.; St. Louis, Missouri, and Pasadena and Berkeley, California.

Now instruments alone can not tell the full story of the central region where an earthquake is felt. For this reason the reports from individual observers are important. While all reports are welcome those from careful and skilled observers are much better, and there is a rather elaborate organization which covers the United States and Alaska. The organizations include the Coast and Geodetic Survey, the National Research Council through its Divisions of Geology and Geography, the Jesuit Seismological Association, numerous universities, state geologists and others. It is customary to outline the area affected by an earthquake by so-called isoseismal lines or lines of equal intensity. There are many complications including that of proper intensity scale into which I can not enter, but in order to have these reasonably correct we must have a large number of records to eliminate uncertainties.

When severe earthquakes occur in any part of the earth the news is of interest and it is often very desirable to know at once where they occurred. For example, several years ago there occurred a great earthquake in central China and

through instrumental means this was known months before the arrival of any news. The position of the Grand Banks earthquake of November 18, 1929, which occurred at 4:00 P. M., was known by 9:00 P. M., though the position was beneath the sea, and later study did not change the position from the general region. This is accomplished by an organization which is now almost worldwide, of which an important share is due to American initiative and organization. The information is sent in code from seismological stations in many parts of the United States, Canada, Pacific islands and the west coast of the Pacific Ocean. From these the positions of the epicenters are determined at the office of the Coast and Geodetic Survey at Washington, redetermined at St. Louis University, and the combined results are then sent out to all who have cooperated. Science Service has an important place in the plan, and bears most of the expense. In addition, information is sent to Europe the night following the occurrence by addition to the weather message sent by the Weather Bureau through Arlington. This is rebroadcasted by Eiffel Tower. In addition to news value, seismologists find the information useful in the interpretation of their records.

Work is being done on all the problems that I have outlined, but I do not wish to close without making it clear that the engineering and insurance problems are not being overlooked. The American Society of Civil Engineers has had a committee which has collected information regarding types of buildings and structures which have withstood earthquakes. Building codes have been improved and design of large buildings has been given special consideration. Recently large dams and bridges in regions subject to earthquakes have been designed to resist earthquakes. Leland Stanford University is operating a large shaking table sixteen by twenty feet, on which large models of structures can be tested. Its motions can be made to simulate an earthquake, and all that is needed to make results of very great value is adequate funds for preparation and test of structures. Structural design is receiving much attention at the California Institute of Technology. Several engineers of prominence who attended the World Engineering Congress at Tokyo are greatly concerned in the expansion of the engineering phases of the earthquake problem after seeing what is being accomplished along these lines in Japan.

Insurance problems have received a good deal of attention from the National Board of Fire Underwriters and other organizations. It is a difficult problem to fix rates which will not be prohibitive and which will yet protect the companies against a possible major disaster. Organization of cities to deal with a major disaster has also received consideration.

Many things remain to be done, but it is evident that after a period of comparative neglect scientific men in the United States are awake to the challenge presented by the earthquake. Not yet is the effort comparable to that which has been made to solve the problems of fundamental physics or of astronomy, nor is the engineering attack organized on the basis of the important investigations being conducted under the auspices of the great engineering societies. Especially are there lacking the numbers of students upon whom the future of the work must depend for effective progress. However, the program is unfolding, and we are no longer dependent on a severe earthquake to arouse interest to the point of action.

MAPS FOR AVIATORS

By RAYMOND L. ROSS

CHIEF, AIRWAY MAPPING SECTION, U. S. COAST AND GEODETIC SURVEY

WITH the remarkable progress in civil aeronautics, the necessity for federal maps, compiled for the pilot in a rapidly moving plane, soon became apparent. Congress provided funds and authority in 1926 aggressively to aid and encourage the development of commercial aviation, and the task of making the necessary maps was logically delegated by the Honorable Herbert Hoover, then Secretary of Commerce, to the U. S. Coast and Geodetic Survey, with its trained personnel and a modern map-making plant, able to turn out additional work with a minimum increase in overhead.

In the organization of the Airway Mapping Section there is an unusual interlocking of bureaus. Quartered in the building occupied by the Coast Survey as a unit of the Division of Charts, it is also under the direction of the chief of the Aeronautic Branch of the Department of Commerce, from which funds for its maintenance are received. The arrangement is comparable to the organization of the Airways Division of the Bureau of Lighthouses, in its relation to the Aeronautics Branch, having to do with the lighting of airways, the selection of intermediate fields, establishment of radio ranges, etc.

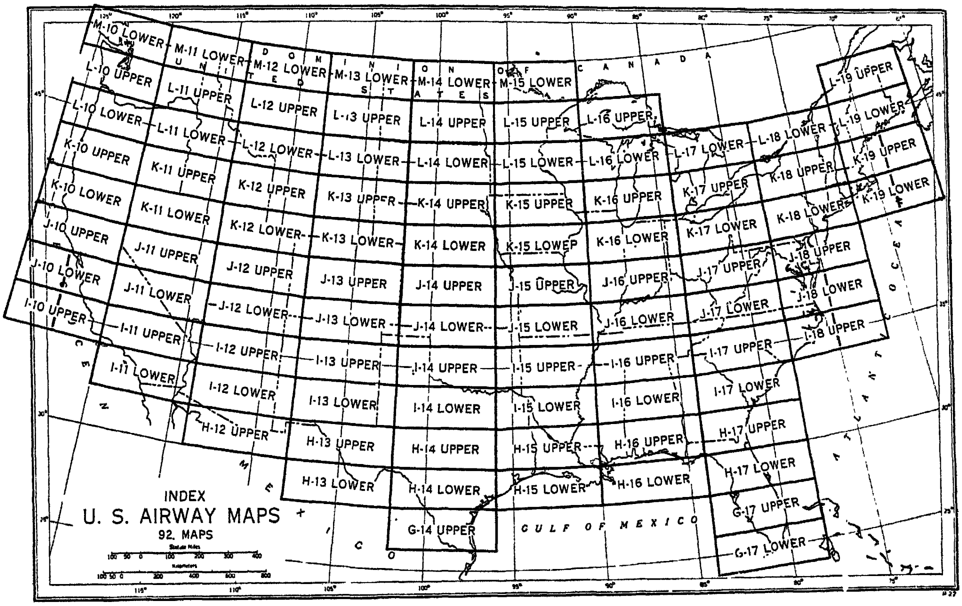
At present these maps are produced from information gathered from a great variety of sources, such as maps of the Geological Survey and General Land Office of the Department of the Interior; Forest Service, Bureau of Chemistry and Soils and Bureau of Public Roads, of the Department of Agriculture; post route maps of the Post Office Department, and state, county, railroad, automobile and other maps of commercial producers, as well as blueprints of various power and light companies. No one of the maps used shows all the features needed. Data concerning intermediate fields and beacon sites are supplied by the Airways Division of the Bureau of Lighthouses, while the positions of airports and auxiliary fields are obtained from the Aeronautics Branch.

The first airway strip map was issued on June 27, 1927, and at this time a total of twenty have been published with three others nearing completion, namely:

102 Dallas—Oklahoma City
103 Oklahoma City—Wichita
104 Wichita—Kansas City
105 Kansas City—Moline
110 St. Louis—Chicago
111 Chicago—Milwaukee
112 Milwaukee—St. Paul
114 Cincinnati—Chicago
115 Louisville—Cincinnati
119 Buffalo—Albany
127 Birmingham—Atlanta
128 Atlanta—Greensboro
129 Greensboro—Richmond
130 Richmond—Washington
131 Pueblo—Cheyenne
132 Los Angeles—Las Vegas
133 Las Vegas—Milford
134 Milford—Salt Lake City
135 Salt Lake City—Boise
136 Boise—Pasco

These, together with the fifty-two airway maps also published by the Army Air Corps, are sold by the Coast and Geodetic Survey at thirty-five cents each, with a reduction of ten cents per copy on all orders for twenty or more.

They are to the scale of 1: 500,000, or about eight miles to the inch, covering



bands of topography along established airways of about eighty miles in width and averaging 250 miles in length.

They are specialized for the use of the aviator in a rapidly moving plane, who must orient himself promptly and has no time to study complex details. They emphasize the relative positions of outstanding topographic features as he sees them, with a limited number of standardized and easily understood symbols descriptive of others. By such symbols he can readily identify Army, Navy or Marine Corps fields, commercial or municipal fields, intermediate fields of the Department of Commerce, marked auxiliary fields, flashing and revolving beacons and other lighting facilities, transmission lines, one track and two or more track railroads, electric railroads and main and secondary highways as well as the towns.

With a map tentatively compiled, a trained engineer makes comprehensive check flights over the entire territory, after which necessary corrections are made and new features added. It is then ready for reproduction and printing.

Symbols for the larger towns are in yellow, with their names emphasized by capital letters. Smaller cities are indicated by uncolored circles and their names given in small type for possible usefulness in emergency landings.

The altimeter carried by the aviator indicates his elevation above sea-level and not the distance separating him from the ground over which he is passing, making information of the altitude and contour of the terrain of vital importance. This is shown by contour lines for every 500 feet, with their elevation above sea-level indicated. High points are also shown, so the pilot may fly at an altitude sufficient to clear each hill and mountain range and, when desired, use the passages between.

Green is used to indicate the lower altitude and brown the higher. The deepest green shade shows from sea-level to 1,000 feet, while the deepest shade of brown is used to depict the highest altitude, namely, from 9,000

feet to the maximum elevation included within the limits of the map. A lighter green is used to show from 1,000 to 2,000 feet, while brown tints are utilized to indicate elevations above 3,000 feet, the brown color being shaded progressively darker for 5,000, 7,000 and 9,000 and high altitudes.

The compilation of what will be known as sectional airway maps—a new undertaking—has now been started, since it has developed that over 75 per cent. of the annual flight mileage is away from the regular commercial airways. They will gradually replace the airway strip maps. The indexing system will harmonize with the International Map of the World, but the scale of the sectional airway maps will remain the same as that of the strip airway maps. In a general way, the first ones will cover areas where the strip map program is complicated by their crossing and overlapping in following the commercial airways. A total of ninety-two section maps will be required to embrace the United States, although it is possible that this number may be somewhat reduced by an alteration of the program along the Atlantic and Pacific coasts.

A RISE DOWN THE CANYON

By Professor ELLIS W. SHULER
SOUTHERN METHODIST UNIVERSITY

EARTH sculpture, in the semi-desert mountains of western Texas, is always puzzling even to the trained geologist. There is everywhere evidence of the erosive power of water, yet seldom is water to be found. The deep canyons are evidently cut by stream action, but there is to be seen not even the smallest stream to do this work.

The explanation is the thunder-shower and the cloudburst. This agency, since the dry soil is not covered over thickly with vegetation, may produce incredible results even in a single storm. Down the dry canyon sweeps a wall of roaring, frightful flood; then all is quiet and dry for weeks, perhaps months of time. In the brief period of flood more is accomplished than in years of quiet flow with normal rainfall.

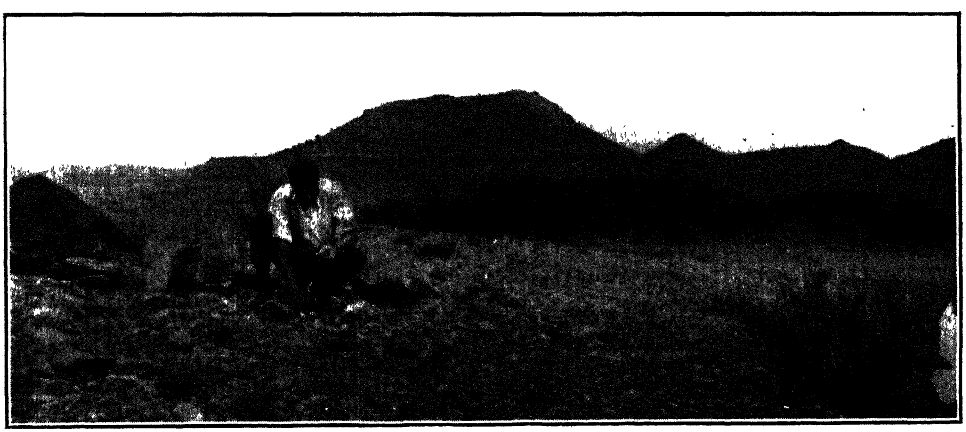
Such a rise was seen by the writer last summer, and what is more unusual, he was able to record it in photograph.

"A seven-foot rise down Limpia," announced the hotel clerk to the guests on the porch at Fort Davis.

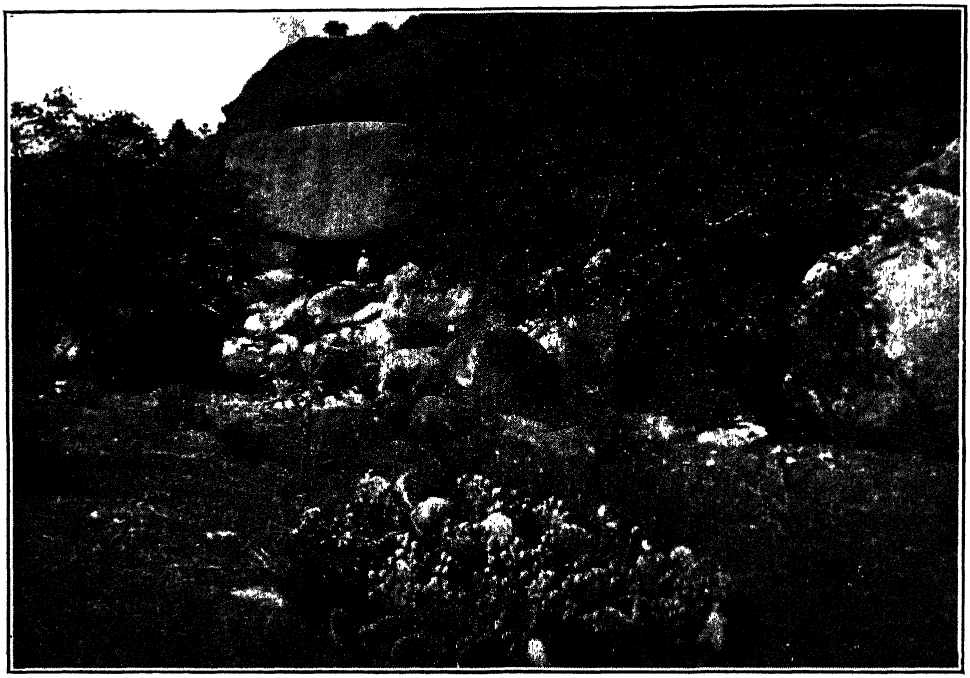
Early in the afternoon a thunderstorm had raged high up in the Davis Mountains, although no rain had fallen at Fort Davis.

Mr. Henderson had just told the new guest how he and a party of friends had been caught in such a rise the week previous. They had entered the stream thinking they could cross before the water drowned their car, but when the engine was killed they had to abandon the car hastily and wade to the bank. One woman had fallen into the current in her haste, to the great peril of her life. Then, hemmed in by two fords and a steep cliff, the party had spent the night around a camp-fire in the rain while the car was carried down stream.

Below the old fort there is a crossing which in previous years has taken more than one life. About an hour after the phone call the cavalcade of



DAVIS MOUNTAINS SOUTH OF FORT DAVIS



INDIAN SHELTER ROCK ON POINT OF ROCK WEST OF FORT DAVIS

hotel guests motored to this crossing. (Future tourists may be interested to know that a newly located state highway and bridges will make the canyon safe and even more interesting than formerly.)

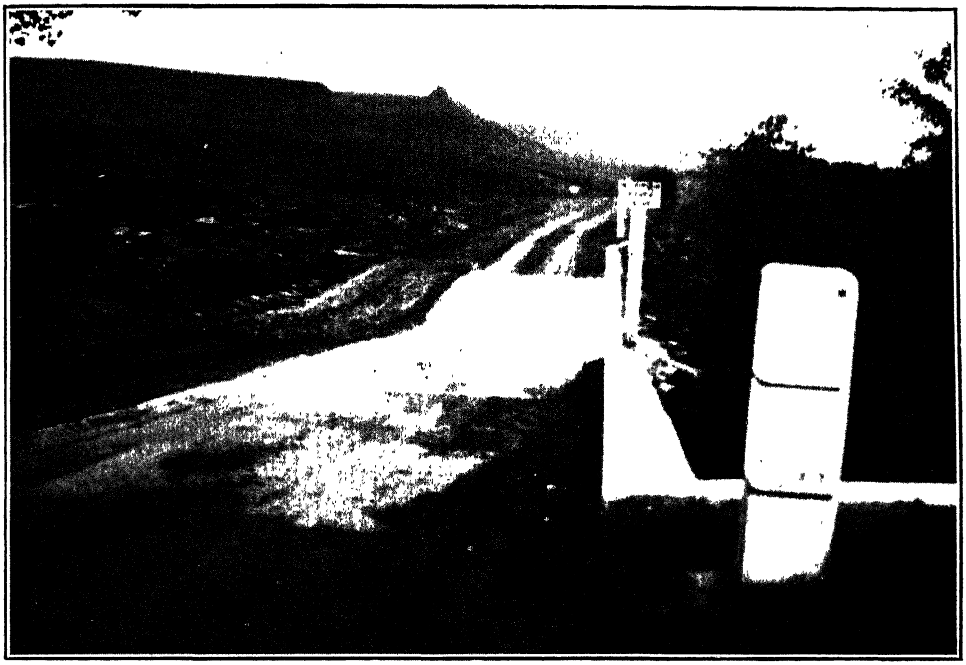
Runners had been sent to warn campers, for despite repeated warnings, the shade of the cottonwood trees and the grassy bottoms along the canyons prove at times irresistible to the transient motorist. Natives of the region, too, who have seen the phenomena over and over again are never quite convinced that they can not "beat the rise," most often to their sorrow.

When the cavalcade arrived, the road crossing, a dip, was dry. In making a dip the bed of the stream is covered with concrete to prevent scouring. Posts are erected at the crossing with markers which show the depth of water running over the concrete slab and thus indicate the danger of the crossing.

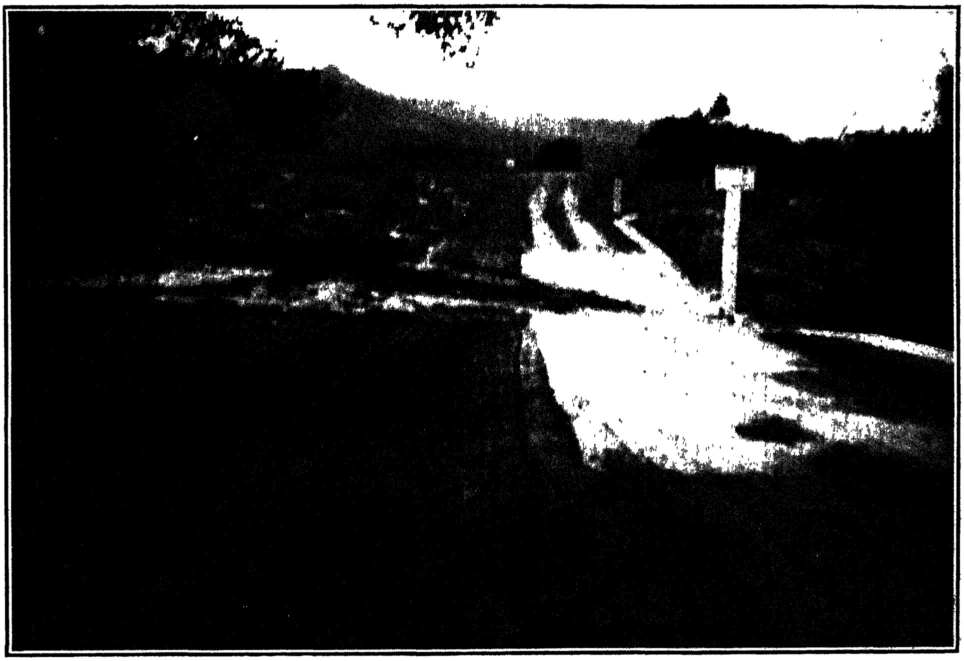
It was 5.30 P. M., and the sun was shining. There was nothing to indicate the near presence of a raging torrent, and a little boy insisted that he be allowed to cross to the other side.

Presently in the distance came a murmur of waters, not alarming, but insistent. Then came a hissing, black, roily tongue of water down beneath the cottonwoods. It was not a wall of water, but a live, hungry tongue, black, dirty and covered over with bits of bark. It was a filthy and a fearful thing to see as it ran eagerly ahead of the main water mass..

Then followed the rising flood, filling the canyon bottom. Downward, tumbling and frothing, now arching up in the middle, then leaping in great bounds, thus the yellow tiger waters rushed down the canyon and over the road

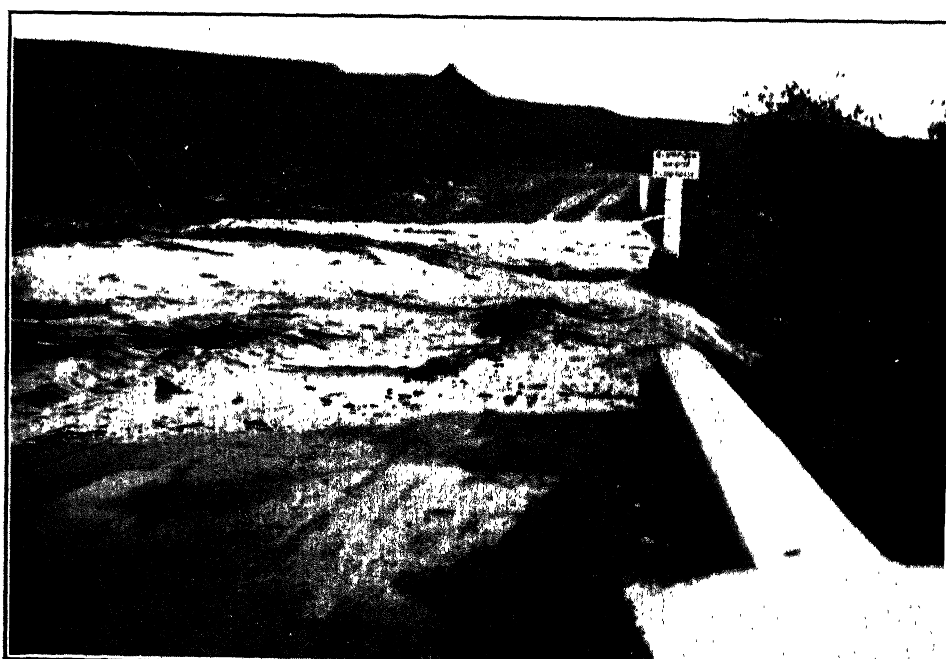


ROAD DIP BEFORE THE "RISE" AT 5:28 P. M.



FIRST THE SNAKE-LIKE TONGUE AT 5:31 P. M.

THE FLOOD IS COME, 5:34 P. M.



AN ANGRY TORRENT, 5:37 P. M.

crossing with a mighty roar and pounding of rocks as the waters dragged them along the canyon bottom or beat them over the concrete slab.

It was a fearful sight; yet there was one thing which amazed. In the quiet of the sunset not a breath of air stirred. In the center of the flood stood three cottonwood trees with not over twelve-inch trunks. The waters swirled around them and beat upon them with savage blows, five or six feet high on the trunks, yet not a rustle or whisper came from the leaves on the trees!

It was exceedingly difficult to estimate the speed of the current because of the crooks and turns of the canyon floor; but from the time of the phone call it had taken the rise two hours to come an air line distance of about twelve miles. Three hours later, the road and dip were dry.

The visitor and tourist who see such a rise will know the explanation for the vivid water-scarred canyons, and he will take care to place his camp high enough along the canyon wall so that he will not be overwhelmed in such a flood.

FOSSIL HUNTING IN THE KARROO, SOUTH AFRICA

By Dr. ALFRED S. ROMER
WALKER MUSEUM, UNIVERSITY OF CHICAGO

SOUTH AFRICA is famous for the wealth which its rocks produce. The greatest portion of the world's gold is derived from the Rand; its mines and diggings have almost a monopoly of the world's supply of diamonds. But the paleontologist, the student of fossils, is not interested (theoretically, at least) in gold or in diamonds, and when he thinks of the treasures of South Africa's earth, it is another type of wealth which is pictured in his mind. Covering half of the extent of the union is a great series of rocks, the Karroo Series, consisting of thousands upon thousands of feet of shales and sandstones and mudstones which, if their total array could be seen at one place would reach nearly six miles in thickness. In these rocks there is no gold, and in most portions no diamonds. But in them are found fossil riches—the remains of many kinds of fossil reptiles which peopled the earth nearly two hundred millions of years ago. It is of a fossil collecting trip to these beds by Paul C. Miller, Walker Museum's veteran collector, and myself, that I wish to tell.

But it is perhaps necessary to explain why we had wandered so far afield, for no other continent has such a great range of fossiliferous rocks as has North America. Our own deposits contain vertebrate remains of almost every period from the remote Age of Fishes to the Ice Age just behind us.

In this series of fossiliferous deposits, however, there is one great gap. The major part of the Permian and Triassic periods is represented by vast thicknesses of strata, but these rocks are almost barren of vertebrate life. This is particularly unfortunate, for these were times when crucial developments were occurring in the evolution of land animals.

In the Coal Measures occur our first records of the amphibians, the earliest vertebrates to adventure out onto the land. Toward the close of this period there first appeared the reptiles, from which all higher vertebrates have developed, and in Texas the "red beds," of slightly later (Lower Permian) age, have a wealth of primitive reptilian forms.

But with this our American record closes for a time. Despite repeated search, not a fragment of bone has ever been discovered in our abundant rocks of later Permian age. Still higher are more red beds, of Triassic age, in which vertebrates are still extremely rare. When we next find a good series of fossil-bearing strata we have reached the Jurassic, the heart of the Age of Reptiles, and all the varied reptilian groups that make this age so interesting are there on the scene. Dinosaurs of all sorts, flying reptiles, water reptiles, even the first birds and the early mammals have all made their appearance. The transitional stages, by which the primitive sluggish reptiles were transformed into these varied types, are for the most part not to be found in North America, and in Europe conditions are little better.

But in South Africa a different situation exists. The Karroo Series is composed of rocks of Permian and Triassic age. The lowest part, corresponding to

the fossiliferous beds of North America, is almost completely barren. Just at the point, however, where the story stops in this country it is taken up in South Africa, and through thousands of feet of rock thickness there are found plentiful remains of the animals of the middle and upper portions of the Permian and the greater part of the Triassic. Some of these are relicts of the primitive reptile groups. Others appear to be early ancestors of the dinosaurs and other reptilian forms; but by far the most interesting and abundant animals are a varied host of reptiles which belong to a group leading to our own relatives, the warm-blooded mammals.

Three quarters of a century ago fragments of bones from this region attracted the eye of a military engineer building roads across the interior of Cape Colony and were shipped to London to be examined by Sir Richard Owen. He, despite antipathy to the then newly expounded Darwinian ideas, could not help admitting that the greater portion of them appeared to be representatives of a group of reptiles intermediate in structure between the primitive reptiles and mammals. Later H. G. Seeley, of King's College, London, worked to some extent in this field. Our present interest in this fauna, however, is mainly due to the work of Robert Broom. A young Scotch doctor, much interested in the origin of mammals, he went to South Africa just before the opening of the present century and has spent his life in the study of these early ancestors of ours. He has described a vast array of interesting types, and has been able to demonstrate that we are actually dealing with a group which was structurally antecedent to the mammals. Watson, of University College, London, has, through careful morphological studies, added depth to the picture painted by Broom, while Haughton, of the South African Museum and the Geological Survey of the union, has contributed much to our knowledge of the fauna.

Walker Museum of the University of Chicago has long been interested in Permian vertebrates. More than a dozen trips to the Permian beds of Texas by Miller have yielded a large amount of material, which was described by the late Professor Williston and his students and which has added much to our knowledge of the early land verte-

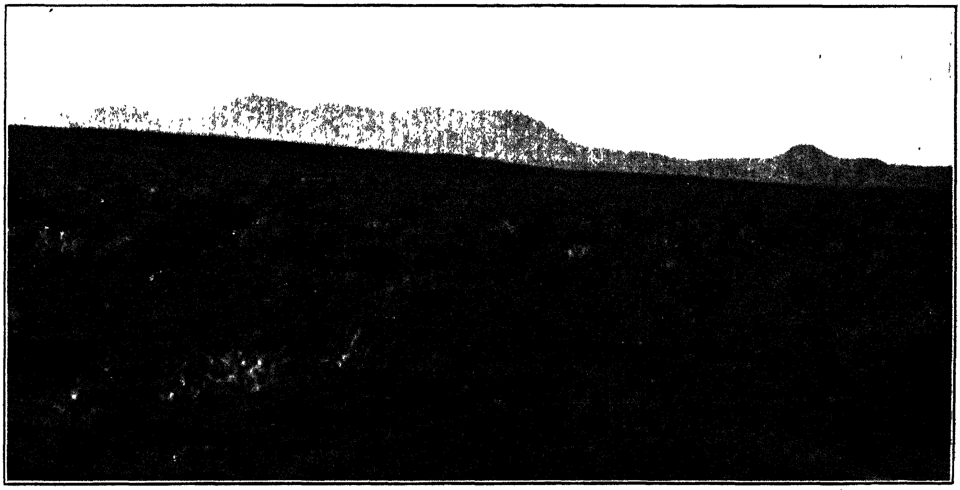


FIG. 1. A TYPICAL KARROO LANDSCAPE
A BARREN, GRASSLESS PLAIN. THE NIEUWVELDT MOUNTAINS IN THE BACKGROUND.

FIG. 2. LOOKING DOWN ON MILLER ALONGSIDE A PAREIASAUR SKELETON

brates. We have wished to expand the museum's work in this Permian field. But, as we have seen, this has been impossible in America. Our eyes for years have been turned toward South Africa as a region in which we desired to work.

This field, as I have said, was not an untrodden one. But despite the fine accomplishments of the few men who have worked on these Karroo vertebrates, the fauna is such a vast one that great lacunae still exist in our knowledge, and we felt that Miller's Permian field experience, if utilized in South African work, might result in the collection of material of considerable scientific value. And so it was with high hopes that Miller and I early last year found ourselves enabled, through the generosity of an anonymous Chicago citizen, finally to make the venture.

We landed last April at Cape Town, where we spent nearly two weeks obtaining supplies, a light truck and—just as important—advice. We found our scientific colleagues in South Africa most helpful. Dr. Haughton, of the South African Museum, gave us much good advice based on his personal knowledge of the Karroo, and later, when we got in touch with Dr. Broom, he too was able to furnish us with many valuable hints.

Out from Cape Town we traversed the narrow coastal plain and then began the crossing of the great ranges which parallel the coast. Over them the roads are, fortunately for us, well constructed, for they were made as military roads nearly a century ago. Railroads then were undreamed of, and good communications had to be furnished with the interior, where there was then intermittent fighting with the natives. Farther inland, the roads fade out. The main highway between South Africa's two

largest cities, Cape Town and Johannesburg, became merely a rut which it is hard to follow across the veldt. There are no bridges; when the road reaches a river, one plunges down the bank and makes his way as well as he can across the sandy river bed and up the opposite bank. Usually the rivers are dry. If it rains—well, one simply camps on the bank and waits a few days until the water runs off.

Four hundred miles across country, and we had reached our first destination, the edge of the Great Karroo. The term is a Hottentot one, meaning a desolate country, and we found no reason to disagree with this description. The region consists of a series of plains and plateaus, with an elevation ranging from two to six thousand feet, extending across much of the interior of Cape Province. To the south, high ranges cut off moisture-laden winds from the coast, and the prevailing winds are from the barren deserts to the northwest. The rainfall is consequently very small. In the poorest part of the Karroo, in which we first worked, it was, on the average, four inches a year, and in some sections there had been not a drop for five years. There is no grass, and agriculture is, of course out of the question. There are, however, small drought-resisting bushes on which sheep can somehow manage to make a living, and so the country has been settled by a hardy race of Boers. Since it takes on the average ten acres to support one small sheep, it may be imagined that their ranches (optimistically called farms) are necessarily of large size and the density of population very thin. About every hundred miles or less, however, there is a small "dorp" where supplies may be obtained.

Nothing more unlike their native Holland than this present home of these Dutch settlers can be imagined. (There is a story of a modern Hollander who was persuaded to buy a farm and emigrate to the Karroo. He stayed just six months, and then abandoned the "farm" and fled.) Their hold upon a livelihood is a precarious one. The only saving grace is the cheapness of native labor; ten shillings and a bag of cornmeal a month is the average wage. But despite their poverty, they are an extremely hospitable people, and we have warm recollections of the many kindnesses which they showed us.

Our first camp was made in the lowest of the many fossil-bearing zones into which the Karroo rocks are divided, in the district between Beaufort West and Prince Albert, Cape Province. We had been warned of the hardness of the rocks and the scarcity of fossils, and we soon found that conditions were as had been predicted. The first day Miller found a good prospect and next morning started optimistically to excavate his find. But when he returned to camp that evening he was quite despondent. He had broken the point off his favorite pick, had broken a cold chisel and had made no impression on the rock. The blue-gray mudstone in which the bones are imbedded is so hard that it is only where a skull or skeleton is weathering out on a flat surface and the rock has largely disintegrated that it is possible to do anything with it. In a number of cases we found good specimens only to leave them in position when we realized that we could not dislodge them without using high explosives which would merely reduce the bone as well as the rock to scrap.

There followed days of almost fruitless wandering over the arid veldt. The fossils were there, and it required merely time and patience before we should make a "strike." Finally, after a week of searching, Miller made our first good find, a practically complete pareiasaur, similar to the skeleton shown in the figure. These forms are rather large

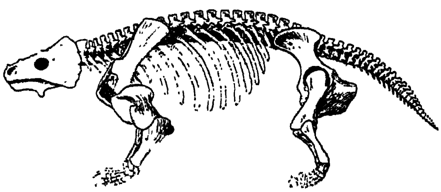


FIG. 3. THE SKELETON OF A PAREIASAUR
AS RESTORED BY BROOM.

and uncouth reptiles, a dozen feet or so in length, relicts from the primitive reptilian fauna and fairly closely related to some of our earlier American types. There are already two mounted skeletons of these curious creatures, one in Cape Town and one in London. We obtained two nearly complete specimens, as well as a large amount of more fragmentary material. One skeleton we hope to mount in natural position; the other, lacking part of the skull, will be exhibited as a slab mount, lying in the position in which it was found in the rock.

The life restoration figured is inaccurate in some respects, but gives an idea of the general appearance of one of these large and uncouth creatures. The best comparison that can be made is to imagine a horned toad from our western deserts about four yards in length. These reptiles were harmless herbivores, subject to attack from carnivorous enemies; and in correlation with this fact we find that there were series of bony plates down the back, the beginnings of a defensive armor.

FIG. 4. A PAREIASAUR
AS RESTORED BY SMIT, IN HUTCHINSON'S "CREATURES OF OTHER DAYS." IT IS INCORRECT IN SOME PARTICULARS, BUT GIVES A FAIR IDEA OF THE GENERAL APPEARANCE.

It will be noted that this skeleton was discovered naturally articulated, "top side up," with the limbs extending down at its sides. The head and tail are the highest portions; the middle of the back is caved in (a feature incorrectly attributed to the animal in life by the restorer). Previous writers had commented on the fact (which we found to be true) that practically all pareiasaurs are found in this position, whereas almost all other animals in these beds are disarticulated. The suggestion has been made, very plausibly, that these pareiasaurs lived in the swamps and mud flats which then covered the region and that the skeletons are those of animals which were actually mired in the mud which hardened into the rock now forming the mudstone matrix.

FIG. 5. A HARMLESS HERBIVOROUS DINOCEPHALIAN
WITH A SWOLLEN FOREHEAD, FROM A SKULL IN THE BRITISH MUSEUM (AFTER WATSON).

Parenthetically, it may be noticed that here, as in later cases, it is the finds of other, earlier workers that I have figured rather than our own. The reasons are, of course, fairly obvious. The casual visitor to a museum seeing a mounted skull or skeleton of a fossil animal may

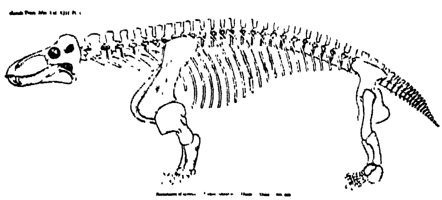


FIG. 6. A RESTORATION OF THE SKELETON OF A LARGE CARNIVOROUS DINOCEPHALIAN, ABOUT FIFTEEN FEET IN LENGTH (AFTER BROOM).

imagine that once the specimen is found in the field and shipped home to the museum, little remains to be done. But in reality, work has barely begun. Freeing a single skull from the matrix of rock which surrounds it is often, under the best of conditions, a task requiring weeks or months of careful work. The Karroo rock has a deserved reputation for toughness, and the preparation of these specimens is far more difficult than usual. It will be years before a considerable portion of our material will have been prepared and placed on exhibition.

A second type of reptiles, of considerably greater scientific interest but tantalizing because of the usual fragmentary nature of the remains, is that represented by the Dinocephalia. The scientific name, "giant heads," refers to the fact that the skulls were enormous, for those days; one which we brought back measures nearly a yard in length. Over the eyes there was, in many cases, a huge swelling, giving a very high-brow appearance to the beast. This, however, was deceptive, for these reptiles were small brained, and this imposing forehead was composed of bone. Some of these giant heads were carnivores; others harmless herbivores. The carnivorous types are very close, it is believed, to the common stock from which the other South African mammal-like forms and their descendants, the mammals, have been derived; the herbivores were a sterile side branch. (It is interesting, by the way, to note that in the evolution of vertebrates it is almost universally the carnivores which have been successful in the long run, and given rise to higher forms, while herbivorous types have their day and then usually disappear without descendants. This is hardly in agreement with some of the pet notions of to-day; and if there is a moral

FIG. 7. A HOTTENTOT SHEEP-HERDER AND HIS SON AT HOTTENTOT'S RIVER. THEY FOUND US A NUMBER OF GOOD SPECIMENS, INCLUDING THE SKELETON SHOWN IN FIG. 2. HE HAD NO IDEA OF THE LOCATION OF AMERICA BUT, AS MAY BE SEEN, HE IS WEARING A CAST-OFF ARMY BLOUSE.

to be drawn from it, I'm sure I don't know what it is.)

Our collections include skulls of both types, but unfortunately no complete skeleton, for, unlike the contemporary pareiasaurs, the remains of these forms are almost always found scattered. Only in two cases have associated skele-

FIG. 8. WINTER COMES TO SOUTH AFRICA
SNOW IN THE NIEUWVELDTS, BEHIND OUR CAMP.

tons been discovered; and we were not fortunate enough to find a third exception to the rule. It is generally believed that these forms lived ordinarily in the higher land surrounding the swamps in which their remains were buried, and that the remains which we find are those of carcasses carried down by streams and broken up on the way.

After more than a month at our first camp we moved some fifty miles farther north to Hottentot's River. We were still in the same zone, but close up under the Nieuwveldt Mountains, which rose some three thousand feet above us to the north of camp. The place owes its name to the fact that this district was still retained by a Hottentot chief after most of the adjoining districts had been settled up. One McPherson, happening by after taking Scotch leave from his ship, married his daughter and inherited the farm. But Scotch thrift is becoming somewhat diluted with the passing of several generations, and we understood that the local villain holds a mortgage on the place, and by now may have foreclosed on McPherson's somewhat dusky descendants.

Collecting here was excellent, including a second pareiasaur (the one figured) and many other finds. We were especially fortunate in finding an unusually intelligent Hottentot herdsman. He had roamed these hills for years with the sheep, and knew every stone on the place. When we finally got him to understand what we wanted, he and his small son were able to lead us to many good prospects, saving us many days of search.

Our memories of this region, however, are somewhat embittered by the weather. It was July, in Africa. But July is, of course, midwinter in the southern hemisphere; we were in the south temperate zone, rather than the tropics (at about the latitude of El Paso) and in the mountains as well. Snow might have been predicted; and snow came. The natives told us that it was the worst storm in fifty years, but that was chill

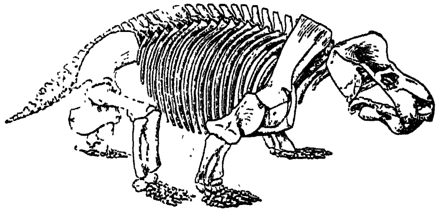


FIG. 10. RESTORED SKELETON OF A DICYNODONT (AFTER H. S. PEARSON).

comfort to us as we huddled about our fire, and we were only too glad when we decided that our bag from there was sufficient and that we should move on to new fields.

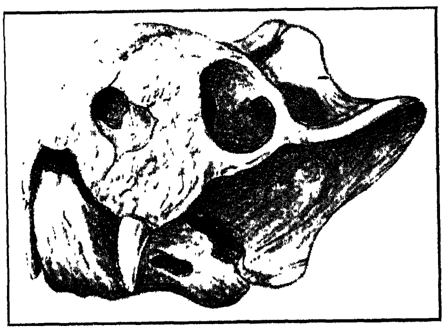


FIG. 9. A DICYNODONT SKULL (AFTER JAEKEL).

We now went farther north and east in the Karroo in among the mountains, in higher beds with a changed fauna. Here we found very few pareiasaur remains, and the "giant heads" had completely disappeared. Instead, the common fossils were those of dicynodonts, "two-tuskers."

FIG. 11. LIFE RESTORATION OF A TUSKLESS FEMALE DICYNODONT (AFTER OSBORN).

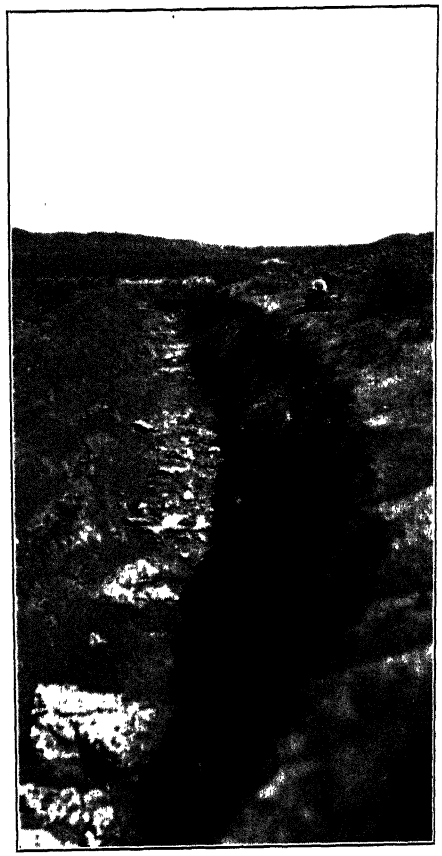


FIG. 12. A GULLY NEAR BETHULIE
MANY OF THE APPARENT BOULDERS IN THE BOTTOM ARE REALLY NODULES CONTAINING DICYNODONT SKULLS.

These forms, like the dinocephalians, were relatives of the mammal-like reptiles, with an advanced type of locomotion in which the limbs are partially brought around under the body rather than sprawled out at the sides in the fashion of primitive reptiles. But their skulls were grotesque. Amongst other peculiarities these strange creatures had lost practically all their teeth. In many cases there was a single pair of tusks in the upper jaw, placed where those of a carnivorous mammal should be, but the rest of the mouth was toothless, and

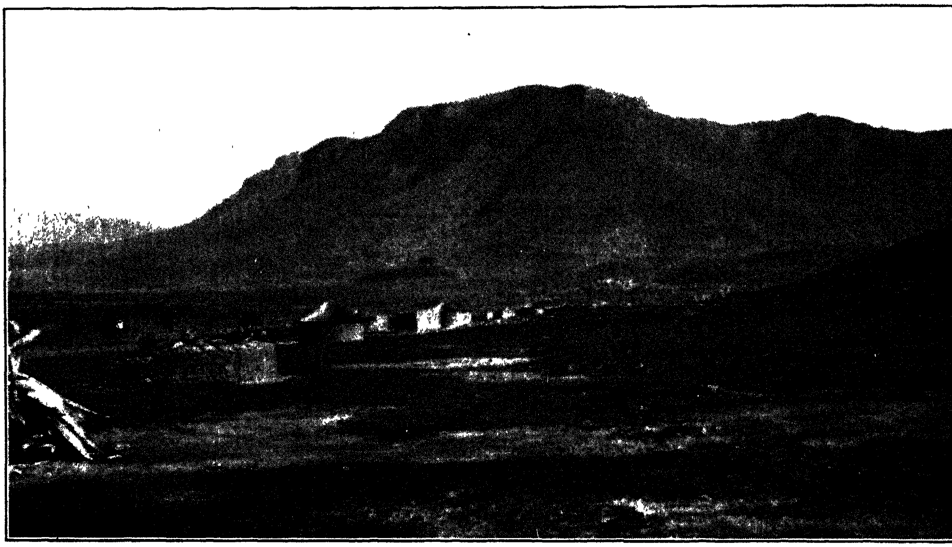


FIG. 13. THE CYNOGNATHUS BEDS NEAR LADY FRERE
THIS MORE FERTILE COUNTRY IS THICKLY POPULATED BY "KAFFIRS," SOME OF WHOSE KRAALS MAY BE SEEN IN THE FOREGROUND.

seems to have been covered in life with a horny, turtle-like beak. Some even lack the pair of upper tusks. These were placed by the older writers in a separate group. Later, however, it was suspected—and it appears to be true—that this difference was often merely a sexual one, the male being tusked and the female tuskless.

At our first stopping place in this zone, Wagenaar's Kraal, the people were of the pleasantest, the fossils of the poorest, and so regretfully we moved on to Murraysburg, a little Dutch "dorp" at the foot of the Sneewbergs. Here we were, comparatively speaking, in the heart of civilization (population 750). There was even a hotel. But we found, after a brief experience, that our camp cots and our own cook's very limited culinary offerings were, after all, not bad by comparison.

Fossils here were plentiful. Dicynodonts large, dicynodonts small, dicynodont skulls, dicynodont skeletons and a sprinkling of rarer things, such as skulls of more typically mammal-like forms and one tiny skull which, although only two inches long, is that of a type believed to be the ancestor of the great dinosaurs of later days. On one hillside finds were so plentiful and so easily obtained that we had to hire a Negro boy to caddie for us to carry loads of fossils from the shale exposures on the hill to the car.

Still farther northeast we pushed to look into the fossil offerings of still higher beds, across the Orange River and into the southern edge of the Orange Free State, near Bethulie. Here we were told that we would encounter remains of *Lystrosaurus*, an aquatic two-tusker, a sort of reptilian seal. And we found them, as usual of course, in the most unlikely spot. Coming along the road we spied a small and rather poor-looking exposure on a small hill, and agreed to stop ten minutes or so, before we went on—"just to be sure there's nothing there." There was nothing on the bare spot. But just below was a small gully cutting through the beds of shale. Into this Miller,

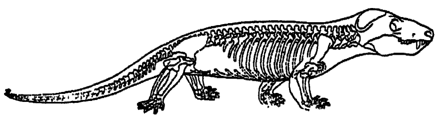


FIG. 14. THE SKELETON OF AN ADVANCED MAMMAL-LIKE REPTILE
CYNOGNATHUS, AS RESTORED BY GREGORY AND CAMP.

with a nose for bones, promptly plunged, to find that what appeared to be a large number of boulders in the bottom of the ditch were really nodules, each containing all or a part of the skull of the creature for which we were looking.

The very highest parts of the Karroo Series center around Basutoland, an almost independent native state in the mountains in the heart of the South African Union. These beds contain a fauna consisting principally of early dinosaurs and their relatives, in which we were not particularly interested. But below them—and higher in the series than we had yet worked—were the Cynognathus beds, which we must investigate in the hope of enriching our collection—all too scanty—of real mammal-like reptiles, the theriodonts.

The beds in which the best-known members of this group occur were well delimited on our maps. But it is known that most of their extent appears to be absolutely barren of fossils, and the known localities had been so thoroughly worked over for specimens of these rare forms that it was hopeless to repeat the search. On this account we were forced to make a stab in the dark and explore comparatively new territory. We first tried the country about Rouxville in the southern part of the Free State. But ten days of search in fine-looking exposures gave us only a few almost worthless scraps. So we decided to make a final attempt, and crossed to the south over the Stormbergs back towards the coast to Lady Frere, where some of Seeley's early finds had been located, and where we had somewhat better luck.

These cynodonts are the highest development of the reptilian ancestors of the mammals, and show many striking resemblances to our warm-blooded relatives. The whole skeleton, especially the limbs, is much more mammal-like than in any other group of reptiles, while the skull is curiously suggestive in many ways of that of such a generalized higher type as the opossum. The teeth, for example, are differentiated into incisors, canines and molars; as in the mammals, the head joins the neck by two condyles, in contrast with the single condyle of ordinary reptiles; the nostrils, instead of opening directly into the roof of the mouth, as in normal reptiles, are sometimes separated from the oral cavity by a hard palate. The Karroo beds are practically the only place where these forms are to be found. In later times, the development of the dinosaurs seems to have caused the extinction of these ambitious carnivores—all, that is, except that one small group which was destined to become the ancestors of the mammals.

We were amazed at the change in the country in the Lady Frere region. We were now back on the coastal side of the range where the rainfall is greater. Here we saw for the first time in six months grass-covered fields on which even a cow could make an orthodox living. Further, while our previous locations had been in country occupied by white farmers, we were now in a

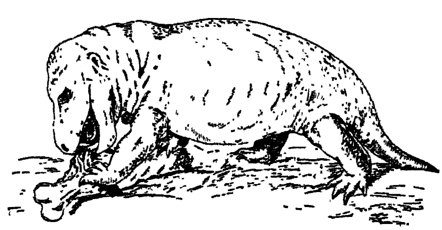


FIG. 15. A SKETCH RESTORATION OF CYNOGNATHUS (AFTER OSBORN).

native district, with Kaffir kraals all about us. Lady Frere is a tiny hamlet in which reside the officials and traders who deal with a surrounding black population of fifty thousand. It proved a delightful stopping place.

It was October by the time we had finished our work here, and the time was approaching when we were scheduled to return to America. And so we shipped our last specimens and trekked back to Cape Town, headed for home.

Our collections are safely back in Walker Museum where the sound of Miller's hammer and chisel may be heard daily as he works on the intractable matrix. The preparation of our finds will be a long and tedious process. But in time this will be accomplished and we can only hope that their study will contribute in some degree, at least, to the scientific knowledge of these ancient reptiles that lived so long ago in Southern Africa.

AN ARCHEOLOGICAL RESEARCH AND ITS RAMIFICATIONS

Dr. A. V. KIDDER

CARNEGIE INSTITUTION OF WASHINGTON

FOR the past fifteen years Carnegie Institution of Washington has been engaged in archeological studies in Middle America, the project centering in Yucatan and concerning itself primarily with the career of the Maya Indians, builders of the highest aboriginal civilization of the new world. The investigations have added to our understanding of the intellectual achievements of the Maya in mathematics and astronomy, have served to point out strategic areas for intensive excavation and, most important of all, have aided in establishing, upon the sure foundation of a dated chronology, the sequence of the principal categories of Maya remains. But proper utilization of these data, in other words their interpretation in terms of history, can be made only in the light of accurate information as to the biological nature of the populations concerned and as to the environment in which they lived. These factors form respectively the raw material of and the setting for the course of historical events, and without understanding of them it is impossible to reach valid historical conclusions. It has accordingly been necessary to call for aid by workers in several non-archeological fields. Furthermore, the principle that in any investigation one should proceed from the known to the unknown, which in archeology means that one should work from the known present back to the unknown past, has induced analysis of modern conditions and consideration of post-conquest history. All this has brought about a concentration in the peninsula of the following researches: Archeological work at Chichen Itza, under direction of Dr. Morley, now in its seventh year; excavation at Uaxactun, Department of the Peten, Guatemala, under direction of Mr. Ricketson, fifth year; hieroglyphic research by Dr. Morley, twenty-fifth year; ceramic survey of the Maya area by Carnegie Institution, inaugurated in 1930 by Mr. Roberts; medical survey of Yucatan by Harvard University and Carnegie Institution, now in its second year; records of the Chichen Itza clinic, third year; biological reconnaissance by University of Michigan, Dr. Gaige; ethnological reconnaissance for Carnegie Institution by Dr. Redfield, University of Chicago; studies of Maya linguistics by University of Chicago, Dr. Andrade, all in their first year. Proposed activities are historical work on the conquest and the colonial period; retranslation and collation of native chronicles; investigation in physical anthropology by the department of genetics; geological, meteorological and agronomic reconnaissances; air survey of the Maya area.

A conference attended by persons directly connected with the above activities and by certain others who were willing to give the institution the benefit of their counsel was held during January at the institution's field headquarters at the ruins of Chichen Itza. The general project was reviewed, and the bearings of its several phases were discussed. Finally, it was possible to formulate a number of problems, specific and general, and to lay tentative plans for

attack upon them. We venture to summarize some of the results as an unusually clear example of the close interrelation which exists between historical research and the natural sciences. They also seem to indicate that coordinated attack upon the highly complex subject of man's career offers unusually effective means for bringing together, both practically and intellectually, workers in different branches of natural science who, in the ordinary course of their studies, would have few opportunities for contact with each other.

Upon archeological questions and archeological method we touch most briefly. But as Maya history is the backbone, so to speak, of the investigation, it is necessary to state that the culture of this interesting people arose, from sources not as yet clearly identified, during the first millennium before Christ. The peak of Maya progress was reached in cities lying at and near the root of the Yucatan Peninsula, a region which was occupied for at least a thousand years and which was suddenly and very mysteriously abandoned about the beginning of the seventh century A. D. Although the old home land was given up and the country reverted to jungle, the Maya persisted on the Guatemala Plateau and in the plains of northern Yucatan. In the latter area they achieved a brilliant renaissance, engaged in severe intercity struggles, suffered invasion from Mexico and were apparently upon the verge of complete political decadence when the Spanish conquest put an end to native civilization. The Maya, however, still form the bulk of the population of Yucatan, and the thread of Maya history therefore runs unbroken to the present day.

Judgment as to Maya origins involves many cultural considerations, but two of the key problems are essentially biological. The first of these concerns the somatological relation between the Maya and other aborigines of Middle America. It must be answered by the physical anthropologist. The second question relates to maize, or Indian corn, for upon that cereal the Maya, and indeed all other new world civilizations, were founded, as those of the Mediterranean were based upon wheat, and those of the East upon rice. Hence the inquiry shifts to the realm of the botanist and the student of plant genetics. The archeologist must depend upon the results of these sciences for information as to the identity and range of the wild ancestors of maize, which he requires for locating the place of origin of American agriculture. The archeologist may perhaps, however, in part repay the debt, as he has already begun to do in southwestern United States, by furnishing ancient specimens of maize from long series of horizons, thus providing the geneticist with datable material for calculating the rate of development of recent varieties.

A very important element of Maya culture was its remarkably accurate calendrical system. The desire to record passage of time seems, indeed, to have led to the invention of Maya hieroglyphic writing. At all events the carved dates of the inscriptions (which are decipherable) give us a precise relative chronology for the principal ruined cities. The details of epigraphic study can not be considered at this time, but it may be remarked that the most pressing question at present is the exact correlation between the Maya and the Christian calendars, a correlation which is now approximate, but which, according to the best authorities, can ultimately be made exact by astronomical and mathematical studies. In the case of astronomy it is to be feared that archeology can make no return for benefits received, but to the history of mathematics and the philosophy of numbers there are offered most interesting materials, for of

all mankind the Maya first arrived at the concept of zero and first practiced positional arithmetic.

Field and laboratory methods in archeology need not concern us here. One may say, however, that success depends upon intensive technological research leading to recognition of chronologically significant criteria, ceramic, lapidary and architectural; upon determination by stratigraphic means of the relative age of materials embodying those criteria, and upon comparative studies to establish the range and to evaluate the importance of different categories of specimens.

The results of epigraphy and archeology can, as has already been said, be understood only in the light of knowledge of environmental conditions. For this we must turn to the biologist, the geologist, the geographer and the meteorologist.

Biological research in Yucatan has hitherto been sporadic and of necessity superficial. It is hoped, however, that the reconnaissance made during the past winter by Dr. Gaige may lead to the undertaking by University of Michigan of an extended ecological investigation. The mere stock-taking of flora and fauna involved in such a project would be of much value to taxonomy and biogeography. It is also absolutely essential to the student of man, for it concerns such basic matters as the nature and extent of resources in game and in food plants, as well as animal and vegetable products useful in the arts, to say nothing of the listing of deleterious factors, such as disease-carrying organisms, noxious species, etc. There are also less obvious questions upon which the biologist can throw light. The *cenotes*, for example. These are well-like breaks in the limestone crust of the peninsula caused by collapse of the roofs of subterranean water-eroded chambers; Yucatan has no surface drainage, therefore in ancient times the only permanent water supply must have come from the *cenotes*. Leon Cole has shown that comparison of the faunas of these tanks can probably be used to determine the extent of underground circulation, a phenomenon which has important bearing upon pollution of drinking water and so upon health conditions. Also from the excavator's standpoint the size of the openings between the *cenotes* is of moment in judging the practicability of pumping them out to recover the wealth of votive objects which were cast into some at least of them.

An ecological survey will have all the usual value of such work. In addition, Dr. Gaige has pointed out certain special studies which can profitably be pursued in Yucatan. These concern adaptations in species, trapped, so to speak, in isolated *cenotes* where they have existed under naturally controlled conditions for varying periods of time presumably approximately measurable by geological methods. Another type of adaptation is illustrated by terrestrial forms, which must have emigrated from the humid tropics as Yucatan emerged from the sea, and which have fitted themselves for life in the arid, subtropical environment of the peninsula. Here again a time-scale can probably be supplied by the geologist, and there may consequently be gathered data as to rate of modification, persistence of traits and other phenomena of fundamental genetic and evolutionary importance.

Dr. Gaige has outlined still another line of investigation, and in this the archeologist can be of assistance. The Maya undoubtedly cultivated very extensive acreages of corn, for the vast extent of their building operations argues not only a great population but a large surplus of food. Forest destruction, either by *milpa* agriculture or by the making of permanent fields, must, therefore, have been enormous. Careful

plotting of the location and size of ruins can in all probability be counted upon to indicate the areas of such denudation, while hieroglyphic, ceramic and architectural studies will determine its age. The biologist may consequently be provided with definite regional and chronological information for research on the succession of floras and faunas and on the rate and order of their return to artificially cleared terrain.

At this point the agronomist enters the picture. He must pass upon soil capacity and former agricultural methods. His decisions are vitally necessary to the archeologist, for the social and economic structures of the Maya were molded by their farming practices. And the judgments of the agronomist working in conjunction with the ethnobotanist will have to be taken into account in all researches which touch in one way or another upon questions of nutrition. For example, Dr. McCollum believes that maize is only adequate as a staple diet under one of two conditions: when there is a superabundance of sunshine, or when maize is supplemented either by green-stuffs or by the organs of animals subsisting on green-stuffs. Now maize civilization originated in arid, sunny plateaus; it eventually spread to less sunny lowlands (as in the ancient Maya country at the south of Yucatan); in many such regions, presumably because of higher returns from agriculture, civilization flowered astonishingly; but increasing population probably eliminated game, the Indians were never given to raising greens and when the Spanish arrived the high maize cultures were either dead or dying in every part of the new world save in regions of excess sunlight. We would not push speculation based on these facts too far, but such thinking adumbrates researches of undoubted significance for the historian, the biometrician, the nutritionist and the student of health conditions.

This brings us to the medical work. Dr. Shattuck and his group from the Harvard department of tropical medicine have now spent two seasons in the field. They have made clinical examinations, have gathered statistics and have conducted specific studies of certain prevalent diseases. They have found the country, for the tropics, unusually healthy, but intestinal and respiratory troubles prove to be extremely common. Yucatan, according to Dr. Shattuck, is admirable territory for studying the very important and little understood tropical anemias, because malaria, which as a rule is so abundant and whose symptoms overlie and becloud the more subtle manifestations of anemia in other regions, is here relatively rare and its effects can, in a general sense, be factored out. As a first step in this investigation Dr. Shattuck has undertaken the determination of normal standards, to be followed by nutritional research, checks of the bacillary and amebic dysenteries and of other pertinent factors. Extension of the work will lead to consideration of the whole question of life in the tropics, involving the human geography of all tropical countries and the ability of various peoples to exist under conditions of heat and humidity. There are naturally involved matters of race, of climate, of food supply, of native and introduced diseases and of the physical properties of the sun and the atmosphere.

General information as to health and accurate knowledge of the nature and the history of specific diseases are, of course, needed by the historian as well as by the student of present-day conditions. The medical man, on the other hand, can not carry his labors very far without being forced to call upon the archeologist for estimate of the location and thickness of early populations; on the paleopathologist for evidence of ancient disease; on the ethnologist for

data as to manners and customs which influence the spread of sickness, and on the biologist, geologist and meteorologist for all sorts of environmental data.

Certain medical investigations are of interest to the historian, to the immunologist and to the student of the spread of diseases. Dr. Shattuck found in 1929, for example, that the Maya Indians were remarkably free from syphilis, whereas the Spanish and mixed bloods were normally infected. Does this indicate immunity derived from prehistoric prevalence of the disease, or have social conditions acted to prevent its diffusion? The matter is being looked into this year. The results may supply evidence upon the vexed question of the new or old world origin of syphilis. Yellow fever, again, has been held responsible by Spinden for the break-up of the Maya Old Empire; but yellow fever is generally thought to have been introduced after the conquest. The malarias, too, are to-day the single worst malady of the American tropics. Were they prevalent in ancient times? The documentary historian, by scrutinizing the records of early expeditions into now infested regions, may well be able to supply pertinent facts.

Work in medicine is intimately connected with that in physical anthropology, not merely because both sciences are concerned with biological aspects of man, but because both deal with basic problems of race, medicine approaching the subject by use of physiological criteria, somatologists mostly by the methods of anthropometry. The recognition of pure, or relatively pure, races is difficult enough, but when one encounters, as in Yucatan, all degrees of hybridization, the task of establishing degrees of admixture becomes so complex as to require use of every possible category of evidence. Anthropometry, however, is undoubtedly the readiest means for arriving at preliminary classification. An excellent start has been made by Dr. Williams under the joint auspices of Harvard and Carnegie Institution. Eighteen hundred individuals have been measured, many blood-samples taken and many observations made on basal metabolism. The results, which are shortly to be published, should serve as foundation for the study, already mentioned, of the place of the Maya in the aboriginal population of America and for identification of the particular Caucasian strains entering Yucatan since 1545, together with the various degrees of Indian-White crossing. Clinical medicine, genetics, sociology, psychology and all other disciplines dealing with race-linked phenomena will directly or indirectly be benefited by continuation of this study.

Geological investigation has not as yet been undertaken, so that it is not possible to make statements concerning the specific questions which will prove of interest to workers in that science. But the findings of geology are essential for many other branches of the survey. The archeologist must have knowledge of the mineral resources of the peninsula in order to determine whether or not objects found in the excavations are of local origin, and to gauge both the amount and the provenience of mineral imports. The ceramicist must learn the extent, location and relative accessibility of sedimentary deposits containing clays. Questions of soil and of water supply are of interest to every one, and are particularly important for the medical group and the agronomists. The age of the peninsula and the rate of its emergence are, as has already been brought out, of great significance for the biologist.

Climate is still another factor of environment which has to be taken into account. The applications of meteorology are naturally legion. Statistics, published and documentary, are now being gathered, and local records are

kept. It is hoped to add further observational equipment when a competent meteorologist can have looked over the field, and shall have consulted as to their special needs with the workers in other sciences.

Geographic data are a by-product of practically every phase of the survey. Together with other statistics they are being collected, by means of the duplicating note-books used by all field men, at division headquarters in Washington. But just as anthropology occupies a central, synthesizing position among the sciences of man, so geography serves to bind together those of environment, and there is, accordingly, need for association with the project of men trained in the latest methods of that science. Particularly will they be helpful in the planning and prosecution of the air survey of Yucatan which it is hoped may shortly be made. By means of the plane the topography of the whole Maya country could be plotted and the distribution of its forest types recorded. Parties on special missions, biological, geological, archeological, could quickly be transported and set down on lakes or rivers otherwise accessible only to large, expensive and time-consuming expeditions.

And so one might indefinitely go on pointing out lines of research and their bearings upon each other. The difficulty lies not in what to do, but in selecting what is most important to do, in deciding how best to do it and in finding the men and the means with which to get it done. No one institution can possibly handle a project so large and so varied. If ultimate success is to be attained it must come through realization by many agencies that the field is a significant one, through confidence that it is being developed in the proper way and through belief that investment of effort in cooperative research will bring valuable scientific dividends.

A few points deserve emphasis. Administrative organization, it is thought, should be flexible. Program must not be rigid. Individual effort should be directed by individual scientific interest. Studies should be coordinated, but they should be carried on independently, should be highly specialized and should pursue definite goals within the limits of the sciences they represent. Any given unit of research so conceived and so prosecuted may be expected to contribute its quota of facts to the corpus of information at the disposal of its mother science, and it should also have influence in development of the methodologic practice and the underlying philosophy of that science. This, of course, is true of all proper investigations, no matter what their immediate aims may be and regardless of where they are carried out. But if, as in Yucatan, a number of such researches be undertaken simultaneously, if they utilize the same general body of materials, employ the best practical and intellectual weapons and if close touch be kept among the workers, it seems obvious that progress must be greatly accelerated, because data will be cumulative and results will be comparable. Mutual concern with inevitably interlocking problems will induce the most natural and therefore the most effective form of cooperation. And without cooperation we can never cope with phenomena too large for comprehension by any one science, but which lie at the root of many sciences. The Walrus, after all, was right. Seven maids and seven mops will eventually make their impression. He only erred in expecting them to finish their job in half a year.

AN EXPERIMENT IN TEACHING

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PERHAPS no teachers in this country give less consideration to or take less stock in pedagogical theory and practice than do college professors. Few college or university teachers, in the biological sciences at least, have ever had special training in the theory and practice of teaching. Whether this is necessary or even desirable I am not saying. It is my opinion, however, that much of the criticism now leveled at the college student because of his disinterest in his scholastic work ought rather to be directed against the professors who teach him. My own experience as a student and as a university professor, now of some thirty years, satisfies me that the average professor teaching college students has little "method in his madness." I myself do not pose as an expert in pedagogy, nor would I claim complete immunity from the above indictments. I only marvel that we who worship so devoutly at the shrine of scientific method should practice it so little in our teaching.

The procedure in presenting laboratory courses in biological subjects to-day is, with rare exceptions, that introduced half a century ago: one or more laboratory exercises per week in which all the students study the same subject and the same material under the solicitous guidance of immature instructors; a lecture or two by the professor, a mass recitation conducted by one of these same instructors or, rarely, by the professor himself, and a voluminous weekly report which is usually only a slovenly and inaccurate misalliance of poorly digested laboratory pickings. In addition to this there is frequently imposed upon the student the handing in for correction (sic) by the overburdened instructors of a written copy of the student's notes taken during the professor's lecture. This is rarely complimentary to the professor, of no interest to the instructors and of questionable value to the student. This, in brief, is the system in vogue, at least in most of the institutions of higher learning in this country.

During the first twenty years of my career as a teacher in Cornell University, I followed this general system with a degree of faith and devotion which I can now only contemplate with a feeling of astonishment and chagrin. During the second decade of this period, I began to be aware of a feeling that something was wrong with my teaching methods. In spite of the fact that, so far as I could learn, the courses which I gave were looked upon with a reasonable degree of pleasure and approval by my students, I still felt that there must be a better way. I sought in vain among my colleagues and the literature on the subject for a procedure which appealed to me to offer a direct solution for my difficulty. Ideas gained from articles I read on the Dalton system and other experiments then being initiated in secondary schools set me thinking. Out of this thinking grew a resolution to attack my teaching problem in the same way that I was accustomed to attack research problems in my field. I decided to experiment. Having won the approval of my instructing staff of this point of view, I spent an entire summer in working out a new and untried procedure. We gave it a trial for the first time that fall semester. This experiment has now been going on for some ten years, and there is every indication that it will continue an experiment to the end of my teaching

days, for each year problems in the details of the method present themselves and each year we attempt by the experimental method to solve them and to perfect our procedure.

I shall now attempt to outline the procedure as it operates to-day and set forth something of the philosophy underlying it and some of the results which I think may fairly be claimed for it.

The course which I am about to describe, expressed in terms of our curriculum, is a three-hour elementary course in plant pathology, of one lecture a week and of nominally two laboratory periods of two and a half hours each. The course in the fall term is limited to fifty undergraduate students. If more than fifty register for it, that fifty having the highest average standing in all their preceding work in the institution are admitted. The remainder are rejected. In the spring term the number is limited to twenty-five on the same basis. Students who because of their low standing have been rejected in the autumn usually get the course in the spring term, when applications are relatively few. The course is open to sophomores, juniors and seniors throughout the university. The only prerequisite is the regular six hours' course in beginning botany. The teaching staff in this course normally consists of myself, an assistant professor, an instructor and a laboratory assistant with an assistant in charge of what is known as the "materials room."

When the students arrive for the first exercise, they are given some mimeographed information sheets in which the manner of conducting the course is briefly set forth. The salient points in the procedure are verbally emphasized at this meeting with the class. The students are then referred to a list of exercises in the information sheets. Here are found fifty-eight exercises only three of which are prescribed for all students. The remaining ones, each dealing with a specific disease of certain plants, are arranged in twelve groups. From each of these groups the student is permitted to select one for study, thus making a total minimum of fifteen exercises to be done during the term. Each student is allowed to select an additional five or more diseases which he may study if time and inclination permit. The average number of exercises completed per student per term is around seventeen.

Having made his selection of exercises with the advice and approval of one of the professors, the student is now ready to begin work at once. He goes to the materials room adjoining the laboratory, where there is checked out to him by the assistant in charge the necessary mimeographed text on the subject, preserved specimens, cultures, slides, photographs and other materials illustrating the disease to be studied. Each student is allowed to have out, at any time, materials for the study of three different diseases, and may with permission of the professor in charge check out more than this under certain conditions. He purchases at the bookstore our printed "Laboratory Outlines" in which he finds directions for study of the laboratory materials, and supplies himself with some plain sheets of drawing paper and drawing pencils. He goes to the department stockroom, where he checks out a complete equipment of laboratory tools, and gets his assignment to a locker. The microscope which he is to use, bearing the same number as his locker, is kept in a case in the laboratory. The specimens and materials which he has checked out from the materials room are handed to him in a shallow tray which slips into his locker. The locker will hold from three to five such trays of material. He is assigned to a table in the laboratory which is his on two specified laboratory periods during the week, though he is free to use it or any unoccupied table in the laboratory at any time throughout

the week, day or night. A laboratory which opens its doors to students at nine and closes them against him at four is an abomination.

The students are now told that they are at full liberty to come and go from their laboratory work as they choose. They are informed that during the so-called laboratory periods from 1:40 to 4 o'clock on three afternoons of the week and from 10:30 to 1 on Saturday morning there will be an instructor in attendance to answer questions and give them such assistance as they may request. The instructor is not permitted to offer advice or assistance to any student unless requested to do so. Outside of these periods students may not ask the instructor for assistance. They are quite free, however, to call on the professors for help at any time.

When the student has completed to his own satisfaction the work on any given exercise he applies for a conference test on the subject. This test may be taken only during the specified laboratory periods. As soon as he has thus prepared himself for the conference, he writes his name and the name of the exercise on which he wishes to have the conference on a small slip of paper and drops it into a slotted box at the materials room. This may be done at any time during the week. He may also designate on the slip the particular laboratory period during which he desires the conference. The slips are taken from the box at the beginning of each laboratory period by the assistant in the materials room, who then displays them chronologically in a special holder so placed that the student can see his position with respect to the others, in the order of call.

Promptly at the beginning of the period, the assistant professor and I appear at the materials room. One of us takes the slip of the first student on the list, the other the next, and each is called to a personal conference in another room. We have tried holding the conference with two or more students ready at the same time on the same exercise, but it does not work. Individual conferences are now the rule. We have in the conference room the necessary blackboard and other facilities for the work.

When the student comes to his first conference, the procedure involved is explained to him. He is told that we assume that he has accumulated a sufficient body of facts and information to enable him to solve a series of problems which will be set for him on the subject. It is pointed out to him that if he does not have the facts necessary for the solution of the problem he of course can not solve it, but it is also emphasized that he may have all the facts and yet be unable to do the mental operations necessary in manipulating these facts for the solution of the problem. In short, it is made clear to him that thinking with facts to solve problems constitutes the test of his accomplishment in his work.

The professor then proceeds to set problem after problem, some of them simple and some of them complex, and the student, standing on his feet without other students to embarrass him or to give him moral or material support, must by word of mouth indicate to the professor the mental operations through which he proceeds in his attempt to solve the problem and arrive at a logical answer or conclusion. When in his hesitation or stumbling it becomes evident to the professor that the student is having difficulties, an attempt is made by asking specific questions to discover whether it is the lack of knowledge of certain facts or the inability to use the facts he already has that is giving him pause in his mental attack on the problem. If the professor discovers that the student is wanting in knowledge of one or more essential facts for the solution of the

problem, one of two courses may be adopted: the professor may *give* the student the facts and then ask him to proceed with the solution of the problem, or he may decide that the paucity of factual knowledge is so great that "gifts" are not warranted, and he dismisses the problem with an explanation to the student of the unhappy situation in the case. He then proceeds to another problem in the hope that here the student will have the essential factual data. It is not the particular facts that the student knows or does not know that appear to me essential, but it is important that he shall have a sufficient body of facts so distributed over the subject as to enable him to operate with them in solving a reasonable number of pertinent problems.

The conference may continue for a half hour or an hour and a half, depending on the number of students who are waiting for conferences, the evident need of the student for mental exercise or for any one of a number of other reasons which will occur to any good teacher. A few well-selected problems will be sufficient to give any competent instructor, within the course of fifteen to twenty minutes, a just estimate of the student's accomplishment in the subject in hand. Thus the least important purpose perhaps of the conference, though a necessary one under our antiquated system of educational administration, namely, that of determining what grade the student should have for the conference, is quickly accomplished. The remainder of the time available for the conference can then be used for the more important purpose of teaching the student how to think with facts which he has accumulated and giving him exercise in this all-important feature of the process of education.

When the professor has completed his questioning the student is urged to present anything which he may have in mind in the way of questions for clarification. Such student questions are answered, where possible, by the Socratic method, thus compelling him if possible to think out the answer to his question himself. Such time as may still be available is often profitably devoted to giving the student new or interesting information along certain lines which would not otherwise have come to his attention in the study of materials or references to literature, and so his knowledge and interest in the subject may be broadened and deepened.

At the conclusion of the conference the student is asked whether he is prepared to accept a grade on his performance for that exercise. He may elect to accept a grade, after which the professor dismisses him and enters his grade in the records in the materials room where it is available to the student at any time after the conference. Or the student may elect not to take a grade at that time but to go back and study the disease further and apply for a conference at some later time, the only provision being that he must take the reconference with the same professor. A note to this effect is made by the professor on the student's card which is returned to the materials room assistant who files it to await a time when the student shall again sign up for a conference on this subject. The student may elect a reconference on any given exercise as often as he chooses with the distinct understanding that his grade will be based on the final performance, when he decides to take the credit. His performance in previous conferences has no bearing whatever on the grade which he finally accepts. Having once declared his readiness to accept his grade, however, he can not thereafter claim a reconference on that particular subject.

A student finding his name well down the list for conferences on any given afternoon need not waste his time wait-

ing for his turn. He proceeds with the study of the next disease of which he has material checked out, until he is finally called. If the number up for conferences on a given afternoon is greater than can be handled during that period, those near the end of the list will have to wait for a conference until a later period, but their names will appear at the head of the list at the next period on which they expect to be in the laboratory.

The attendance at the one lecture in the week is likewise not compulsory. The student may come or remain away just as he chooses without any detriment to his standing in the course, so far as the mere matter of attendance or absence is concerned. Not only is he told that he may remain away from the lecture if he chooses, but provision is made so that he will not be seriously handicapped by such absence. A complete, mimeographed text of the lectures is given out to each student at the beginning of the course. In this are set forth the organization of the subject, the important generalizations with ample illustrative cases and with a well-selected bibliography of references bearing on each subject so that the student will be able quite independently of the lecturer to get all the essential facts, generalizations and conclusions.

The lecture which comes once a week is not given, as is usual, for the purpose of conveying facts, theories, opinions and conclusions of importance to the student. Those he will find in the lecture text. The students are told this at the first lecture with the remark that if they wish to know the purpose of the lectures they may find out by coming to them. The real object of lecturing, as I see it, should be to stimulate and inspire the student to a real interest in the subject; to give "set" as the educational psychologists say and to vivify and adorn important subjects and generalizations. The student should go forth from a lecture with a new eagerness to examine his laboratory materials and with a renewed desire to explore further into the writings of those who have contributed to our knowledge of the subject. A professor who is not an interesting and stimulating speaker should never lecture either to college students or to anybody else. I never criticize a student for sleeping in one of my lectures. If I can not keep him awake he is entitled to all the sleep he can get. It is made clear to the students that no lecture attendance is kept, that they are quite free to come to none or only part of the lectures if they choose, or even to only a part of any one lecture. Coming late to a lecture or going out before it is completed is not a crime. Such incidents are of concern only to the students themselves. A professor who is disturbed by a student coming in late or leaving before he has finished speaking is too nervous to be holding down a teaching position in a university or college.

Yes, there are examinations in this course. One must defer to tradition and custom to some extent. Three unannounced prelims are offered during the term. The student may elect to take these or not as he chooses, but if he takes one he commits himself to the other two. There is a final examination, required of all students through the beneficent action of our faculty. I sympathize with my students, but hold them to it. The final term grade is made up as follows: 50 per cent. of it is based upon the average grade obtained in the conferences; if the student has taken the prelims the average of these counts 22 per cent. of the term grade, and the final examination 25 per cent.; if the student elects not to take the prelims, then the final examination counts 50 per cent. of the term grade.

This, I think, sets forth briefly the present procedure in this experimental course.

I shall now pass to some of the philosophy which I think underlies this procedure. I would point out, in the first place, that every possible responsibility for the work in the course is placed upon the student and is not assumed by the professor as is usually the case. The student is made to understand clearly that his attendance at lectures and laboratory periods is wholly a matter for his own decision. The professor requires nothing with respect to attendance, nor does he concern himself with it. It is assumed that every student taking the course is quite competent to adjust his own coming and going to his best advantage. Failure to do so brings with it certain consequences for which he alone accepts responsibility in registering for the course.

Some of you may wonder whether this procedure operates as effectively with students who are required to take the course as with those who elect it. I can assure you that it does. Approximately half of the students taking the work in the fall term are required to take it by the department of forestry. The department of plant pathology itself requires no student to take any of its courses, nor does the faculty of the college make any such requirement. Our experience has been that while the forestry students often approach it with the well-known attitude of the forced laborer, they quickly succumb to the novelty of personal responsibility involved, and we are soon unable to detect any marked difference between their attitude and that of those who have elected to take the course.

The question may also be raised in your minds as to whether under this system the student devotes the necessary time to the work in the course. You need have no doubts on this point. Inquiries carefully checked have proved that the average student spends nearly twice as much time per week under this system as he did under the old one. This results, perhaps, from the unaccustomed feeling of responsibility which is suddenly thrust upon him. He is not held either directly or by implication to set hours for work nor does any one suggest just how much time he should devote to the work. He has contracted to do a minimum number of exercises; some of them rather short and easy, others long and complicated. He soon learns from his conferences that it is not time spent with the subject but knowledge acquired and usable that is requisite to a creditable performance in the conference or examination. He is compelled to decide for himself how much time he will or can afford to spend on this particular course in relation to the other courses which he takes. The natural result is that he puts in the time required in the other courses, or as little of it as he can get away with, and devotes the rest of his study hours to the course in plant pathology. Students often remark to me that the course takes a lot of time and that if all the courses in the university were taught in this manner one couldn't carry many subjects at any one time. Quite right; but no student ought to expect to carry more than three or four subjects satisfactorily. Under the old system we dragged the students through twenty exercises of the same kind as those of which he now contracts to do but fifteen for the same credit. It is not that the course takes more time; he gives it more. I remind the student that his natural ability, his inclination, his interest and the press of other duties determine the time he spends on the work, pointing out to him that neither by direction nor by implication do I make any demand on him as to the amount of time he is to devote to this course. Here again he is compelled to exercise judgment and accept responsibility.

You will recall that each student makes his own selection of the number

of exercises which he is to study. To be sure this selection is to a slight extent limited by the grouping of the subjects from which he must choose, but where in this world are not our free choices of action more or less limited? At any rate, this freedom to choose what he will study, limited as it may be, has a very happy effect upon the attitude of the average student in approaching the work in the course. He feels that he is studying something that he has chosen to study. It is a mistaken notion, at least in biological work, that the use of one particular species of plant or animal or disease, or whatever, is essential for the demonstration of any principle, theory or general conclusion. Any professor who is so poor in his knowledge of illustrative materials as to feel that only one particular case will serve ought not to be teaching in a university. At least a sufficient wealth of materials should be available to the student's choice that he will have the feeling of interest in his work which comes from personal selection of subject-matter.

The requirement I make of the instructor in charge of the laboratory work that he shall answer questions and give assistance to students only when it is requested will doubtless cause head-shaking on the part of some of you. I would only reply that the universal practice of well-intentioned or meddlesome instructors butting into the student's cogitations with remarks on errors in drawings or other features of his laboratory activities does far more harm than any possible good which may accrue therefrom. When the student asks for assistance or information on a given point he is in the most receptive mood to receive what the instructor may have to offer on the matter. Many students need or require very little instructional assistance in their laboratory work. But, whether they need it or not, it should never be gratuitous. The student should seek enlightenment; it should not be thrust upon him.

The student is informed that he is always at liberty to come either to me or the assisting professor for help in his work at any time. I have no specified office hours for students. The student can always see me whenever and wherever he can find me regardless of what I am doing or with whom I may be in conference or consultation. I regard as my primary obligation that of assisting my students. No matter with whom I may be engaged, when a student appears in my presence with that look of wanting something, which we all know so well, I immediately excuse myself and attend to his wants, no matter if my visitor be the president of the university or the dean of the college. I have seldom found that students come to me with unwarranted demands upon my time or attention. In fact the only criticism I have of them is that they come too seldom and are too much impressed with my apparent professorial busyness. That teacher who is too busy to see his students has no business in a teaching staff. On rare occasions when the situation is such that I can not immediately attend to a student's wants I courteously ask his indulgence but always arrange for a time in the near future when we can conveniently consider the matter. As to the instructor and assistant, since they are graduate students and expected to give but a limited amount of time to teaching, students are informed that they are to be consulted only at the specified laboratory periods, and the instructor and assistant are directed to remind students of this if they are approached outside of these specified times and to send them to me or to the other professor. To be sure, instructors and assistants frequently disregard this command, but I wink at it with the pleasant feeling that they have gotten something

of the spirit of my own attitude toward students.

The conference feature of the course will doubtless arouse questions and doubts in your minds. Does it not require a great deal more time to handle a group of fifty students in this manner than in the old-fashioned way, some one will ask? Emphatically, no. Careful checking on this feature of the work in the early years under the new procedure as against that under the old showed that the conference system actually reduces the amount of time spent by the instructing staff on the course. The actual time devoted to teaching by myself and the assisting professor is twelve hours a week for each of us in the fall term and six in the spring, not counting the lectures and preparatory study. There is no great stack of note-books to be laboriously corrected at least once a week far into the small hours of the night either by professors, instructors or assistants, and what is more important, no need to make the customary pretense at doing so. The student brings to his conference his drawings and such notes as he may choose to make. The drawings are spread out on the table before the professor. He may quickly gather from this display before him the character and degree of accuracy of the mental pictures which the student has of the things he has been studying. These provide the teacher with a basis for many of the problems which he will set for solution, and they are presented at just that time when their presentation is most useful to both teacher and student. The student is not required to make drawings and may appear at the conference without them, in which case, however, he is usually asked to demonstrate on the blackboard that he does have accurate mental pictures of important features of the material which he has studied. There is no virtue in drawings as drawings. Their only value is in sharpening the student's mental picture of microscopic or macroscopic objects, features of importance in the materials which he had before him. Most students make the drawings for the professor, as may be easily proved by listening to their remarks and questions concerning them. Do we have to make these drawings? Just what do you want in this drawing? Is that what you want (exhibiting sketch)—and a dozen similar questions are daily thrown at the professor or instructor in most biological laboratories. Upon the first question of this sort, I always assure the student that "*I* do not want the drawing," that "if I wanted one of that particular subject, I could probably make a better one myself," that "at any rate, I could hire some one who can far outclass *you*." By such replies, kindly put, the student either tumbles to the fact that he is making the drawings for his own edification or he is driven to demand, why make drawings anyway? It is then at the moment of his insistent desire to know why, that I may profitably explain to him the value of careful and accurate drawings for him as means to sharpen and fix valuable mental pictures in his mind.

The time required for the preparation of fresh material, of which much is used in this course, is somewhat greater under the present procedure than it was under the old. Since not all the students who have selected a given disease will be working on it at the same time fresh material for each disease must be prepared in somewhat larger quantity and must be available over a considerably longer period of time. Furthermore, the practice of permitting each student to select his own list of diseases to be studied increases considerably the number of diseases for which fresh material must be prepared and kept on hand. But since the students are thus enabled to work at their own speed and on the

particular disease in which they are interested, the advantages far outweigh in value any saving of assistants' or instructors' time.

In fact, our present procedure requires very much less actual time of the assisting staff than does the ordinary laboratory procedure. There are no materials to be put out before the laboratory by a harassed assistant, rushing back from a hasty lunch. There is no gathering of scattered and wrecked specimens littering the laboratory after the students leave. Each student is responsible for the material he has checked out. He gets it out himself, he puts it away, and when at the end of his conference he returns the material to the materials room, it is carefully checked and any losses or injury to slides, specimens or other permanent material is charged to his breakage, and he pays for it. It is a grand and glorious feeling at the end of a strenuous laboratory period for the weary instructor to gaze upon the laboratory tables free of littered specimens and debris and ready without any effort on his part for the next period. The time thus saved to assistants and instructors in setting up and clearing away laboratory materials is more than ample to compensate for the additional work which they must do in preparing extra fresh materials.

A very important feature of the conference as we handle it is that of leaving to the student to decide when he wishes to take his grade. He is thus compelled to judge his own performance and to request the judgment of the professor as to the worth of his accomplishment. Being permitted a reconference as often as he chooses before accepting the grade leaves him little ground for a feeling of resentment over the grade which he finally receives. I am reminded of one student who, having made a rather poor exhibition, was asked if he was ready to take a grade.

"That was pretty rotten, wasn't it, Professor?" he said.

"Well, it might have been better," I replied, "but it is entirely up to you whether you take a grade or study the exercise some more, and come back for another conference, you know."

"Yes," he said, "but I am so far behind with my work now that I don't think I can afford to take the time to study this further. Guess I'll take my grade."

"All right," I replied, and went to the materials room to enter up the grade. He put away his materials and called out as he passed me, "Would you mind telling me what grade I got?"

"D," I said, "is the best I can do for you on that."

"Just about what I thought I'd get," he said in a disgruntled tone.

"My judgment was good, wasn't it?" I asked. A smile replaced the scowl on his face as he replied, "It certainly was."

In all our contacts with students whether in the laboratory or conference room we treat them as gentlemen and ladies. I never scold a student or bawl him out for poor work. If he is satisfied to do that kind of work and accept the consequent grade, that is his business. I have long ago divested myself of the feeling that poor work on the part of the student is any reflection on me, in spite of the fact that I may sometimes, of course, be responsible. I refuse to harbor any feeling that the student is doing the work for my benefit or glorification. On the other hand, I frequently ask the student after an exhibition of poor accomplishment if he would not be interested in knowing what I think is his difficulty. If he replies in the affirmative, I attempt in a kindly manner to explain to him where his difficulty lies, even to the extent of telling him that I think he is lazy. I have not yet brought myself to the point of telling a student

that I think he is dumb, even though I may be quite sure that is his malady. On the other hand, I never lose an opportunity to give a student a good word for an especially excellent performance. Praise is far more effective in stimulating a student than is harsh criticism.

Now a word as to what I think are some of the outstanding results from this method of procedure. Effective thinking, *i.e.,* facility in manipulating facts so as to arrive at logical conclusions, is, to my mind, the primary test of an educated person. Along with this, of course, comes the having of facts with which to think. A broadly educated man is one who has a good stock of facts on a great variety of subjects and is able to think with these facts intelligently and effectively.

The common practice of college professors in requiring primarily that a student shall accumulate facts to disgorge them on demand is, I think, one of the chief indictments of our college and university educational procedure. Bare facts are of themselves of no intrinsic value even though without facts the student can not hope to do any thinking. Facts are of value only as they afford materials for thought. It seems to me, therefore, that our constant aim should be not only to teach the student how most quickly and effectively to accumulate facts, but, what is more important, how to use these facts in thinking, that is, in solving problems and deriving conclusions, or in other words, making judgments. Too much emphasis in our college teaching is put on getting the facts but almost none on using them. To expect students to be zealous in the gathering of facts to be parroted back to the professor is absurdly naive. To take it for granted that students will effectively use the facts which they have accumulated without exercise in doing this exposes a childish faith in humanity quite inexcusable in a college professor. Yet nowhere in our usual teaching procedure is any provision made for giving the student exercise in the manipulation of the facts which he has learned.

It is in just this point that I feel our method of teaching makes its greatest appeal for approval, and this is borne out by the actual results as we watch the increasing facility with which the students in this course meet the problems which are presented for their consideration week after week. It is also proved by the growing eagerness and pleasure showing on the face of the student as he comes in succeeding weeks at the call for his conferences. At the first conference, hesitation and dread of the approaching ordeal usually show clearly on his countenance, but when he finds that the conference is only an opportunity for him to pit his wits against problems to be set for solution by a friendly professor, he comes to look upon the impending contest with the same joy of battle that inspires the football player or any other participant in a similar contest. I can not refrain from telling an incident in one of these conferences. Having set a rather difficult problem for a student with care in stating the conditions, I leaned back in my chair and awaited his operation. Plunging into the problem he was soon off on a false trail. I halted him with "Wait a minute, let me ask you a question." Judging he was not using a fact which he probably had in the back of his head I so set the question as to bring the fact to the fore of his mind. Immediately without giving the factual answer he replied, "Oh, yes, may I start again?"

"Certainly," I replied, and he was off now on the right track. Time after time, for a half hour or more I brought him up sharply with such a question, when I saw he was getting off the trail, and time after time he reacted in the same way with the reiteration, "Oh, yes, may I start again?" Finally, having worked

the problem out to a satisfactory and logical conclusion, he drew forth his handkerchief and wiped the streaming perspiration from his brow. "Pretty tough wasn't it," I said.

"Yes, but it was interesting," he replied with enthusiasm.

One marked advantage of this procedure is that each student can now work at his own speed and convenience. It is well known, of course, that no two students will cover the same ground in the same time. Some will wish to do only the essential minimum; others will want to explore various enticing side issues and matters of special importance to them. One does not usually study and learn to best advantage when he is constantly under the pressure of a time limit to his mental activities. The opportunity to suit his working hours to his convenience is also, I think, an important matter for the student. To be compelled to come to a laboratory on the afternoon following a wild night out or when he is half sick is not only irksome but futile in its results. It would always be much better for the student to sleep off his debauch or go to bed with his cold and come to his work later in a state of mental freshness. Under such conditions to come by compulsion at a specified time almost always results in a wasted afternoon. Nothing is accomplished, and the needed recuperation from loss of sleep or indisposition is denied him. He will generally leave the laboratory with the feeling that he has, at least, put in his time and so has met his responsibility in the matter, so that when mental alertness is again his happy possession he dissipates his energies in inconsequential activities with no feeling of responsibility for devoting them to acquiring the knowledge to which he has already paid the courtesy of an unprofitable gesture.

Another result of this procedure is that I now have all my time for real teaching. Much time and energy has been spent in working out the details of what I call the "machinery" of the course, in setting up the laboratory materials, *i.e.*, in preparing sets of specimens, photographs, etc., so that every student may have at his disposal the full quota of materials for each exercise. Careful thought has been given to the details of laboratory routine, so that no student will have to wait idly for any length of time in checking out specimens or in getting his conferences, etc. It is surprising how little hitches in matters of this kind will demoralize and nullify the teaching program, so that time devoted to their solution is time well spent in giving to the professor that complete freedom for effective teaching which the student has a right to expect. Assistants and instructors, trained and efficient in the routine of preparing satisfactory and effective materials, are an absolute requisite to this type of teaching. The excuse so commonly offered by professors that they do not have such assistance is not worth the breath it takes to make it. It is the professor's business to see that he has the necessary personnel and equipment for teaching. Otherwise, he should refuse to attempt the work and let the authorities above him take the responsibility. The responsibility for the common situation of an overburdened teaching staff, *i.e.*, a staff too small for the number of students taking the course, lies directly with the professor in charge. Firm refusal to accept more students for a course than can be properly taught with the staff available is not only the responsibility but the prerogative of the university or college professor. So long as he will accept more students than his facilities permit him to teach effectively he has no one to blame but himself. I would resign my job and work with my hands for a living before I would submit to such a situation. If all teachers in colleges and universities

would adopt this attitude and limit registration in their classes or offer their resignation as an ultimatum for the necessary facilities, the problem of poor teaching now so acute in colleges and universities would be largely solved. No really good teacher is likely to be fired from an institution for such action, at least, from an institution deserving of his services and devotion. As a result of adequate machinery I now come to my teaching with a feeling of enthusiasm and freedom from impending difficulties which I never knew before.

Another result is that I am always in a good humor when I come to my classes. There is nothing the student has done or can do to rouse my ire. There are no rules or regulations which I have made that the student can break and so irritate me. The student comes in the same frame of mind. He is not compelled to abide by any attendance regulations, nor must he accept my judgment of his work except at his own expressed desire for the same. Thus we both approach the hour together with the feelings of two friends who sit down together to pit their wits in pleasant and profitable contest. We meet as friends and part as friends. And finally, what is most important of all, the student has, at least, fifteen adequate opportunities during the term to exercise his mind with facts in the all-important educational process of solving problems, arriving at conclusions and making judgments on things in which he is presumably interested.

ELEMENTS OF ISOSTASY—OBSERVATIONS AND INTERPRETATION

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ISOSTASY is a comparatively new branch of geophysical science but a very important one. It is a condition of the outer portion of the earth which must be reckoned with when making investigations to disclose the cause or causes of the great changes in geographic positions and elevations of the earth's surface during geological times.

MEANING OF ISOSTASY

According to the idea of isostasy there is some depth below sea-level where the pressure exerted by the outer portion of the earth is the same on equal areas of a level surface at that depth. Above that depth there are variations in the density of the material, for in order to have equal pressures for equal areas the mass must be the same. Since the volume changes or varies the density must likewise vary. In other words, the product of the volume of a unit section of the earth's crust and the density of the material must be a constant around the whole earth above this depth, which is called the depth of compensation.

With a perfect isostatic earth and with no shifting of load on the earth's surface there would be no stresses present in the material of the earth below the depth of compensation. Necessarily there are stresses between that depth and the earth's surface, for there are great differences in the elevation of the solid surface of the earth in relation to sea-level. The Himalayan Mountains rise to elevations of more than five miles, and there are depths of water in ocean areas greater than six miles. There must be a stress difference exerted from a continent towards an adjacent ocean basin. This stress difference does not become zero until the depth of compensation is reached.

In computing the stress difference between a continental and an oceanic area necessarily the weight of the water must be taken into account. Correct values for the stress difference can be obtained by reducing the volume of water to that of an equivalent mass of surface rock. The density of sea water may be assumed to be 1.01, and a fair value for the density of surface rock is 2.70. A depth of water of about 2.7 miles is therefore equivalent to a layer of rock about one mile in thickness.

The depth of compensation has been derived from geodetic data and has been found to be of the order of magnitude of sixty miles. This depth has some uncertainty, but it is probable that the true value lies somewhere between forty and eighty miles below sea-level. It is my belief that the uncertainty in the derived depth is not greater than ten miles and that the depth lies between fifty and seventy miles. A knowledge of the exact depth is really not so important in geophysical and geological investigations as the idea that there is a depth at which the pressure of the superincumbent masses is the same for equal areas.

ISOSTASY IN INDIA

There are traces of the isostatic idea in some of the literature of one hundred or more years ago, but nothing very definite was set forth until the middle of the last century. John H. Pratt, when attempting to derive the figure of the

earth from triangulation and astronomical data in India, was struck by the lack of harmony in the observed data. He published the results of his investigations, and then George B. Airy, astronomer royal of Great Britain, gave an interpretation of the inconsistencies which had been found by Pratt.

On a hypothetical earth with a perfectly smooth mathematical surface the lengths of degrees of latitude would increase from the equator towards the poles. On the international spheroid the length of a degree along the meridian at the equator is 68.708 miles, and at the poles 69.407 miles. On an ideal earth if astronomical observations for latitude were made at places along a meridian and these places were connected by triangulation to furnish the distances between contiguous pairs of astronomical stations a gradual increase in the lengths of the degrees of latitude from the equator toward either pole would be found.

The Indian data showed great irregularities in the lengths of degrees of latitude and these were thought to be due, in large part, to the irregular surface of India and the areas to the northward. When corrections were applied to the astronomical observations to offset the attractive effect of the masses above sea-level the data were not improved. The corrections for the masses were greater than were needed to bring the triangulation and astronomical data into accord.

Airy suggested that the reason for this was that the crustal material varied in thickness and that under the continents it extended far down into the interior of the earth, which he supposed to be very plastic. There were according to him roots or protuberances of light material which floated the continental masses high above the dense material which lies under the ocean areas. He likened these continental masses to blocks of ice which float in water with a large portion of the block exposed. Pratt took exception to Airy's interpretation and advanced an alternative one. His idea was that the outer portion of the earth varies in density from place to place but that the variation extends to a uniform depth below sea-level. He questioned the validity of the hypothesis that there could be roots extending into subcrustal space below a mountain or plateau area.

Deflections of the Vertical and their Causes

For many years astronomers have been determining the right ascensions and declinations of stars and have collected data which enable them to predict the relative movements of the stars. The stars are not fixed. They wander around the heavens, but their movements are very slow. But even though the unaided eye would need centuries or perhaps thousands of years to detect any real difference in angular distance between any two stars, yet with the high-grade instruments used in the determination of latitude and longitude a star is found to have a different position each time it is observed. The work of the astronomer enables the geodetic engineer to compute the exact declination and right ascension of a star for any instant of time, and from these data he is able to determine accurately the latitude and longitude of a point on the earth's surface.

As is well known, the surfaces of the oceans of the earth have the general form of a spheroid of revolution. If there were no irregularities in the earth's surface and the densities were normal everywhere, this water surface would be a true spheroid of revolution. Since the earth's surface is irregular the continents tend to deflect the plumb line, to which all astronomical observations are referred, from the direction at

right angles, or normal, to the mathematical surface—the spheroid.

It is possible to determine the astronomical latitude of a place with a probable error of 0.10 second of arc or less, while in longitude determinations the probable error is seldom greater than .03 second of time. The actual error in linear measure in the determination of an astronomical latitude is believed to be seldom greater than about twenty feet.

We now know the shape and size of the earth with a fair degree of accuracy. With this knowledge we are able to start from an astronomical station and measure distances and directions across a continent by means of triangulation and to compute the positions of the stations on the adopted spheroid. Triangulation, as is well known, is a system of surveying based on the elementary mathematical principle that if the length of a side of a triangle and the two adjacent angles are known the lengths of the other sides can be computed. In practice a side of a triangle called a base, varying from five to fifteen miles in length, is measured directly by means of steel or invar tapes or wires. The probable error in the length of a base derived from direct measurements is seldom greater than one part in a million, which is all the accuracy required. At intervals of one hundred miles or so, depending on the character of the terrain, additional bases are measured in order to check the lengths carried through the triangles by computation.

From the triangulation data one is able to compute on the spheroid the latitude and longitude of each of the triangulation stations. Any errors in the geographic positions are due in part to the uncertainty in the adopted values for the dimensions of the earth and in part to errors of observations in the triangulation. These errors are comparatively small. If the astronomical latitude and longitude are determined for a number of the triangulation stations, a comparison of the astronomical and geodetic positions at each of these stations gives the values of the deflections of the vertical.

The deflections of the vertical may amount at some places to thirty seconds of latitude or longitude or even more. The linear distance on the earth's surface corresponding to half a minute of latitude is about one half mile. This is so large that accurate surveying and mapping can not be based on a number of detached astronomical stations. The triangulation connecting these stations gives the distances with great accuracy, and therefore the geographic positions determined by geodetic methods are used in the surveying and mapping of continents and in the charting of the waters along the coasts. The map for any particular continent or country is really based on an average value for the latitudes and longitudes which are determined astronomically. Latitudes, as is well known, are merely the angular distances to the north or south of the equator, and longitudes are the angular distances to the east or west of some fundamental meridian. The initial meridian in use generally over the world to-day is the one through the observatory at Greenwich, England.

The deflections of the vertical are due mostly to the irregular surface of the earth and the isostatic compensation of the topographic features. When corrections are applied for the effect of topography and compensation there remain residuals or unexplained portions of the deflections. These residuals are undoubtedly caused by variations from normal density in rock comparatively near the astronomical stations. There may be a large trough filled with unconsolidated sediments near a station, in which case the residual deflection would be away from this area. On the other hand, there may be an outcrop of Pre-

cambrian rock underlaid near the earth's surface by igneous rock. This material is denser than normal and therefore the residual deflection of the vertical will be towards it. Buried structure is indicated by the residual deflections, and therefore geodetic data in the form of astronomical determinations of latitude and longitude and the latitudes and longitudes determined by geodetic means may be of great assistance in both theoretical and economic geology.

Isostasy in the United States

The equilibrium hypotheses of Airy and Pratt received only scant attention for some years. In 1889 Clarence E. Dutton, a member of the U. S. Geological Survey, advanced practically the same ideas as Pratt and Airy regarding the equilibrium of the earth's crust. He seems to have derived his ideas from a study of geological phenomena only. He refers only casually to the work done by geodesists in connection with the triangulation and astronomical data of India. Dutton's exposition of the idea of isostasy started discussion and arguments, but it is rather remarkable that he had very few active followers. Most of the students of the earth of his day were opposed to his views.

During the past few decades rather extensive tests have been made of isostasy, and we now can say with assurance that isostasy in its general aspects is true. Much more must be done in the way of detailed investigations and observations to learn if possible the exact depth of compensation; whether the Airy or the Pratt idea is the true one, and how large in horizontal extent is the block of the earth's crust which can be taken as the unit of mass. It is certain that geodesists and geophysicists will work intensively on these problems, and it is expected that in the next decade much more will be learned of the details regarding isostasy.

Maintenance of Isostatic Equilibrium

In order properly to explain isostasy and the geological processes one should begin at the time of the origin of the earth when it became a separate astronomical body, but this would require more space than is available in this paper. We may assume that the earth has approximately the same size now that it had when it first had a solid surface; or to put it another way, its shape and size now are approximately what they were at the beginning of geological history, which presumably was at the beginning of rainfall, erosion and sedimentation. We are vitally interested only in the processes which have shaped the earth's surface since the beginning of sedimentation and which now are continually changing it. We need not know what was the original condition of the earth, whether it was a molten mass or solid throughout in order to be able to study the processes which are now in operation.

The work of the geodesist and the seismologist proves very conclusively that the outer portion of the earth to some limited depth (the geodesist has found it to be approximately sixty miles) is solid and that it resists the stress differences which tend to flatten out the surface into a smooth mathematical one. The results of their observations and analyses of the data secured indicate that the earth is solid from the crust down to a great depth below sea-level. There is still some uncertainty as to the physical condition of the materials near the center. This involves about an eighth of the earth's volume. The transverse or elastic earthquake waves will not go through that core. If the earth were elastic throughout the elastic waves would pass through the center. The conclusion seems to be that the core of the earth is either a liquid or a non-elastic solid.

The proof of isostasy leads to the definite conclusion that the material below the crust, that is, below a depth of about sixty miles, is plastic to long continued stresses. The observations of earth and ocean tides, of the variation of latitude and of seismic phenomena indicate that the earth as a whole is solid and has a rigidity about twice that of steel, or if the core of the earth is a liquid then the remaining solid part of the earth has an even greater rigidity. These observations, however, involve forces which change phase rapidly. They do not act in the same direction for great lengths of time. It is possible, of course, for a material to be rigid to short continued stresses but to yield if stresses are applied for a long time.

The reason why we conclude that the material below the crust acts as if plastic to long continued stresses is that all land areas in which isostatic investigations have been made show a high degree of equilibrium. Certain areas may have been subjected to erosion for a long time but the pendulum observations and deflections-of-the-vertical data indicate clearly that they are not lighter than normal. Similar data indicate beyond doubt that portions of the crust covered by thick beds of recent sediments do not have more mass than normal.

We may assume that the normal mass is contained in a block of the earth's crust whose surface elevation averages about zero. Such blocks are along the margins of continents. The blocks of the crust which are undergoing erosion must be lessened in mass as a result of the removal of portions of their surface material, but there is an influx of subcrustal matter into crustal space to offset the loss. This lessening in weight or mass would surely be detected by an analysis of the geodetic data in the region in question if there had been no upward movement and addition of subcrustal matter. There is only one way for a block of the earth's crust undergoing rapid erosion to maintain its normal mass or weight, and that is by an intrusion of subcrustal material into crustal space. The block of the crust becomes light as the result of erosion and is buoyed up and elevated by the plastic material which lies beneath it.

In areas of sedimentation along the margins of tidal waters, or even in lakes or valleys, the crust yields beneath the added load and there is a sinking of crustal material into subcrustal space. Since the weight of the eroded material is equal to that of the material deposited as sediments there can be a restoration of the isostatic balance by a horizontal movement of subcrustal material from beneath the area of sedimentation towards the one undergoing erosion.

The Earth a Yielding Mass

All the above may seem very strange, for we are inclined to think of the earth as a very unyielding solid mass. But gravity and deflection-of-the-vertical data are accurate, and the conclusions drawn from them seem to be able to withstand the most critical analysis. The seismologist tells us that the earth is not a rigid body, that is, it is not rigid to long continued stresses. Not an hour passes during which there is not an earthquake somewhere on the earth. It has been estimated that there are approximately eight thousand earthquakes recorded annually on the seismographs now in operation. The number of seismological stations is quite small and many earthquakes of a local and minor nature are not recorded. It would be mere guesswork to say how many earthquakes occur during a year, but it is reasonably certain that the number is several times eight thousand. Earthquakes are caused by breaking or slipping rock. A few may be due to explosions near volcanoes, but these are rather small when measured by the en-

ergy involved. The large earthquakes are the result of movements of crustal material without any accompanying explosion.

If the earth can have thousands of earthquakes per year it is surely not a fixed body, that is, it is not fixed in form and in the relative positions of its particles. Movements must be going on continuously, although in most places the rate of movement is so small that it would take years with refined methods and measurements to detect it.

We do not have to depend on earthquake and geodetic data to show that the earth has been unstable in past geological times and is now unstable. There are few places on the earth's land surface which do not show that they were at a former time below sea-level. This is indicated, of course, by the presence in the rocks of fossils of marine life. Even on the slides and slopes of the highest mountains marine fossils can be found. Areas which are now occupied by the Himalayas, the Alps, the Rockies and the Andes were in an earlier geological time below tidal waters. These areas now have mountain peaks standing high above the sea. Even though it has been some millions of years since they were below sea-level, yet geologically speaking the rate of elevation of those mountain areas has been quite rapid. Areas once occupied by the mountains which furnished the sediments that were later raised into the present mountain masses now lie near or even below sea-level and are receiving new masses of sediments.

The best geological evidence available indicates very definitely that all mountain and plateau areas were once areas in which great masses of sediments had been deposited. There must therefore be some process operating in the earth which is closely connected with sedimentation and mountain and plateau building. It seems evident that the mass of some blocks of the earth's crust is made smaller by erosion and that of other blocks is made larger by sedimentation provided there is no movement of subcrustal material to restore the balance.

The earth's crust must be very weak to yield to the forces involved in erosion and sedimentation, for it is certain that a deficiency or excess of load or mass amounting to a disk of surface rock of indefinite horizontal extent and a thousand feet thick could be detected easily by means of gravity data. There are geological evidences that ten thousand or more feet of material have been eroded from some areas and that thirty thousand feet or more of sediments have been deposited in others. Using a thousand feet of material as the minimum amount that could be detected by geodetic evidence we should still have to conclude that isostasy is in a high state of perfection. I am convinced that the masses of the earth's block do not deviate even a thousand feet from normal. A disk of a thousand feet of material of indefinite horizontal extent would cause a variation from normal gravity of about thirty parts in a million. No such deviation from normal gravity occurs over any large land area which has been investigated.

Study of Gravity Anomalies by Grouping Stations

There are, of course, gravity anomalies which are larger than thirty parts in a million, but the area within which such large anomalies obtain is small. A brief report entitled "Isostatic Condition of the United States as Indicated by Groups of Gravity Stations," Serial No. 366 of the Coast and Geodetic Survey, shows very clearly that the average anomaly for a portion of the area of the United States about 350 miles square is quite small. In fact, there are only a few sections of the country of that size where the average anomaly is more than

about fifteen parts in a million or the equivalent in mass of a disk of rock 450 feet thick. This is an exceedingly small amount of material as compared with the great masses which have been eroded from mountains and plateaus and carried to tide waters and to lakes and valleys.

The mean of the average gravity anomalies for the thirty-eight squares or sections into which the country is divided is only −.004 dyne. This of course shows that the United States as a whole is not underlaid by an excess or deficiency of crustal material. Since one part in a million is the attraction of a disk only thirty feet thick, four parts in a million is equivalent to only about 120 feet. This, however, does not represent a true departure from isostasy, for the theoretical formula on which the anomalies are based may not be absolutely true and this residual may represent an error in it rather than a measure of the departure from equilibrium of the crust under the United States.

Explanation of Gravity Anomaly

A gravity anomaly is the difference between the observed value of gravity and the theoretical value. If the earth had a perfectly smooth ellipsoidal surface and if for any latitude the densities along radii varied in the same way, then the variation of gravity on the surface would follow a very definite law. The actual sea-level surface of the earth approaches very closely to an ellipsoidal surface, and gravity observations are referred to it. The change in the value of gravity with change of elevation is well known, and a correction can be applied to the observed gravity to reduce it to sea-level under the point of observation. Corrections can also be computed and applied to the observed value of gravity for the effect of the topographic masses, which are the masses above sea-level or the deficiency of mass in the ocean waters. Finally a correction can be computed and applied for the effect of the isostatic compensation or the deficiency in density in the crust below mountains and islands and the excess of density in the crust beneath ocean areas.

If these corrections are applied to the theoretical value of gravity at sea-level at the latitude of the station the difference between the resulting value and the observed value is the gravity anomaly. Sometimes the corrections referred to are applied to the observed value of gravity in order to reduce it to sea-level below the point of observation. In this case the difference between this corrected value and the theoretical value at sea-level at the latitude of the station is the gravity anomaly. The anomaly has the same value in either case of course.

Studies of Isostasy in Canada

Some of the most valuable geodetic data used in isostatic investigations have been obtained by the Dominion Observatory, Ottawa, Canada. That organization has made a gravity survey over parts of Canada, and a recent paper by Mr. A. H. Miller, of the observatory, entitled "Gravity in Western Canada," gives data for sixty-nine gravity stations. Many of these stations are in high mountainous areas, and it is very remarkable that the anomalies are exceedingly small even though the average elevation of the stations is great. As a matter of fact, there are forty-three stations of the sixty-nine which have elevations greater than 1,000 feet, while sixteen stations have elevations more than 2,500 feet. There are only three stations at elevations above 2,500 feet which have anomalies more than twenty parts in a million.

The data secured by Miller lead one to believe that the mountain areas of Canada are in a high state of equilibrium. Gravity data in mountainous

areas in other parts of the world lead to the general conclusion that mountain masses are not extra loads added to the crust beneath but that they are balanced by a deficiency of mass in the crust under them. Where there is so much topography, that is, mass above sea-level, a small anomaly is an indication of only a small percentage of departure from the true isostatic state. But even these small anomalies are not positive evidence of a real departure from isostasy, for they may be due to irregularities in density distribution near the gravity stations. They may also indicate an erroneous value for the computed topographic effects as the region near a station may not have been completely mapped.

Miller made a computation of the depth of compensation from his gravity data at twenty high stations in the Rocky Mountains. He concludes the discussion of the depth of compensation with the following sentence: "Evidently the most probable depth of compensation for the twenty stations is between 85.3 and 113.7 kilometers, possibly slightly less than 100 kilometers." The most probable value for the depth of compensation derived by an analysis of the deflection and gravity data in mountainous regions of the United States is ninety-six kilometers, or approximately sixty miles. It is rather interesting that this value and Miller's should agree so closely.

Determination of Depth of Compensation

It is impossible to obtain a correct value for the depth of compensation by the use of gravity stations which are on extended plains or in wide interior valleys. If there were no errors in the observations for gravity and if there were no other causes for the anomaly than the compensation of the topographic features then it would be possible to derive a depth which would have a fair degree of accuracy from plains stations and stations where the average elevation around the station is not great. We know, however, that the cause of at least a large part of the gravity anomalies is the effect of masses of material close to the stations which have abnormally heavy or light densities.

Where the average elevation of the topography close to the station is great then there is a large effect of this compensation on the value of gravity. Even though there might be abnormally heavy or light material close to the station, the effect of the compensation would overbalance this, and we should be able to obtain a depth value which would have much strength. If we should take many gravity stations in high areas then the effects of the local divergences from normal densities on the various stations would tend to balance out, and the derived value for the depth of compensation would be very strong and probably very close to the truth.

At Seattle, Washington, which is quite far from large masses of topography, the gravity anomaly, after the isostatic reduction has been made with a depth of compensation of 113.7 kilometers, is ninety-three parts in a million of gravity. The elevation of the Seattle station is less than two hundred feet above sea-level and the attraction of the topography in the vicinity of the station is not more than about six parts in a million. We can see that no change in the depth of compensation used could materially reduce the anomaly, which is many times six parts in a million.

It was mentioned above that the station must be surrounded by an area having large masses of topography. This statement applies to stations which may be at sea, either on ocean islands, over the margins of continental shelves or

over great ocean deeps and submerged ridges. What are really needed are large masses of topography and irregularities in the elevations or depths of this topography in order that a fairly accurate value may be obtained for the depth of compensation.

The method of determining the depth of compensation has been criticized by some opponents of isostasy. We assume that the crustal material extends to a uniform depth and then compute the effect of the isostatic compensation distributed uniformly to various depths differing successively by several miles. From the data secured we are able to determine the anomalies for each of the several depths used. That depth should be the most probable one which makes the sum of the squares of the anomalies a minimum. The method of determining the depth of compensation is set forth in some detail in Special Publication No. 40 of the Coast and Geodetic Survey.

This method of determining the depth of compensation may enable us to tell whether the Airy or the Pratt idea of isostasy is the true one. Eventually we may secure a great amount of gravity data in each of the great mountain systems of the world. If the Airy idea is the correct one we should obtain derived depths which will vary directly as the average height of the mountain area. There is more topography to be compensated for in the Himalayas than in the Rockies, and therefore if mountain masses are upheld by roots those extensions into subcrustal space should be greater for the Himalayas than for the Rockies. We shall have to wait for the solution of the question until we have vastly greater amounts of gravity and deflection data in the areas covered by the great mountain systems.

Horizontal Extent of Compensation

One of the problems of the future will be to learn whether an area of small extent is underlaid by crust which is not of itself in isostatic equilibrium. It is certainly true that a mountain peak such as Mt. Shasta or Pike's Peak is not compensated for by a deficiency of material immediately below. If the compensation is strictly local then each column of material a few hundred feet or a few miles in diameter, extending from the surface to the depth of compensation, must have a deficiency of mass equal to the mass above sea-level. Undoubtedly there is regional compensation of topographic features such as mountain peaks and mountain ridges, but I do not believe that the compensation that balances such features extends for great distances around them. The data available at present do not enable us to derive the exact distances to which the compensation extends, but after considering all geological and geophysical facts the most probable conclusion is that the compensation does not extend as far as fifty miles around any topographic feature. However, this is not based on definite evidence. It is hoped that future data will enable us to throw light on this very interesting subject.

Denudation and Sedimentation

The student of the earth necessarily is anxious to solve the problems involved in the great changes which have occurred on the earth's surface during geological time. In the absence of definite information we can only guess at many of the possible causes. Some of these guesses may be close to the truth and some may be far from it. In any event, we know one cause which is surely a fundamental and important one. That is the shifting of masses over the earth's surface as a result of denudation and sedimentation. These processes work slowly when reckoned in terms of the length of human life but in terms of geological time they are most important.

The amount of rain to-day over the land surface of the earth averages about

thirty inches per year. At this rate a mile of rain would fall in about two thousand years. In a billion and a half years the amount would be approximately three fourths of a million miles of rain. We use a billion and a half years because that represents, according to best geological and geophysical evidence, the time elapsed since geological processes as we know them to-day first began their operations. The beginning of the sedimentary age of the earth was a long time ago. Sediments of course can not be carried without running water and an irregular surface of the earth, and running water requires rain. We may therefore conclude that rain began falling about a billion and a half years ago, that it probably has continued to the present time without interruption and that in the beginning the earth's surface was irregular.

Rainfall causes an enormous amount of denudation. According to measurements of the U. S. Geological Survey the amount of material carried from the United States to tidal waters is the equivalent of one foot from the whole surface of this country in nine thousand years. At this rate a thousand feet of erosion would occur in nine million years, or a mile in forty or fifty million years. During the sedimentary age, at this rate, there might have been thirty miles of erosion, but of course no such amounts could have been eroded from a given region, because even the highest areas like the Himalayas would be reduced to sea-level long before any such amounts were eroded.

According to the isostatic idea much more material must be eroded to base-level a mountain area than exists above sea-level at any one time, because as erosion continues there is a rising up of the subcrustal material below to restore the isostatic balance. If the difference in density of the surface and the lower portion of the crust is 20 per cent. there should be an upward movement of the crust of eight hundred feet as one thousand feet is eroded from the surface. An area would be decreased only two hundred feet in average elevation by the erosion from it of one thousand feet of material.

As sediments are laid down the crust beneath surely sinks under them. Some of the sinking is due to causes that are independent of the weight of the sediments, but undoubtedly the pressure of the sediments is an important factor in the movement.

The isostatic condition of the crust seems to be maintained almost to perfection. This condition has probably obtained during the entire sedimentary age. If this is true then the crust of the earth must give way to stress differences caused by denudation and sedimentation. Undoubtedly the maintenance of the isostatic balance is a very important factor in geology. Much has been written in geological literature of the crushing, folding and overturning of strata in uplifted areas. In general the authors have either stated or led the readers to infer that most of this uplift and distortion occurred during the growth of the mountain systems. In my judgment much of this movement and distortion has been due to the moving upward of the earth's crust under areas of erosion to restore the equilibrium.

Since under sediments the earth's crust is depressed to maintain the equilibrium, it is reasonable to suppose that much of the breaking and folding of strata occurs as the sediments are laid down. Sedimentary material is usually deposited irregularly along a coast. At one time a river's mouth may be at a certain place on the coast and at another time some thousands of years later it may be a hundred miles or more away. This irregularity in time and place in the way the sediments are laid down leads to irregularity in the strata.

Although the records of the U. S. Geological Survey indicate that the rate of denudation from the United States is equivalent to one foot in nine thousand years, this does not represent all shifting of material in our area. Much of the eroded material from a high mountain area or from a dissected plateau region does not reach tidal water. It is deposited in the foothills or out on the plains just beyond. Apparently a much more rapid rate of erosion takes place from a region of high elevation than from the area of the United States as a whole. This leads us to believe that the rate of uplift in a mountain area to restore the isostatic balance is far greater than that for the United States as a whole.

Mountain Formation

Many mountain areas have been elevated and then later depressed below sea-level. In some cases this has occurred several times. Do we not here find a correlation between the erosion and the sedimentation on the one hand and subsidence and elevation on the other? An area which in one geological era is receiving sediments and being depressed and in a later one is being elevated shows that the placing of sediments must have some effect on its changes in elevation.

For the first mile and a half below the earth's surface we know that the temperature is increasing with depth. During sedimentation the earth's crust is depressed an amount approximately equal to the thickness of the sediments. Every part of the depressed crust goes into a zone whose normal temperature is higher than that of the zone previously occupied. Later on there is undoubtedly some uplift of the sedimentary area due merely to the normal thermal expansion as the crustal material takes on its new temperature. But this thermal expansion would be only approximately three thousand feet even for a depression of thirty thousand feet, and this estimate is based on the assumption which can not be strictly true that there would be no heating of the crust while it was sinking under the weight of the sediments. There must therefore be some other reason besides the normal thermal expansion to cause an area to be elevated a mile or more following a period of sedimentation.

Some areas which have been high and subjected to denudation are now low or even below sea-level. Here we have the opposite process to that which affects the crust under an area of sedimentation. As denudation progresses the crust beneath is pushed up by subcrustal material to restore the balance. This brings the crustal material into higher and presumably colder zones. As the moving material assumes the temperature normal to its new position the decrease in temperature causes it to contract. A depression of the surface results and a trough may be formed into which new sediments tend to be deposited. The depression of such an area is probably much more than would be caused by normal thermal contraction.

The depression and the uplift of areas must be due to a large extent either to some chemical or physical changes which cause increased or decreased densities of crustal material, or to forces acting tangentially in the earth's crust which tend to compress certain areas and to elevate them, and to expand and depress other areas. The writer believes that the changes in elevation, aside from those due to normal thermal expansion and contraction, are due to chemical or physical processes which change the density of the crustal material.

Recently the writer had a conversation with Professor Charles P. Berkey in which the question of isostasy and of the maintenance of the isostatic equilibrium of the earth's crust was discussed in some detail. We agreed that erosion

and sedimentation are factors in changing elevations of the earth's crust, but Professor Berkey held that denudation and sedimentation are not the most important factors in the uplift of mountains and plateaus. He holds that the story of such uplifts could be told if we knew more about volcanism and of the behavior of igneous rocks. I can subscribe heartily to that view. Undoubtedly volcanism is a very important factor, but the question of whether volcanicity, or that which causes it, is the principal factor involved in uplift is debatable. As is shown above, the pushing down of the crust into hotter zones by the weight of sediments and the movement upward of the crust to restore the balance under areas of denudation may be a primary cause with volcanicity as the secondary one. In any event, to cause an uplift of the earth's surface to the extent of one mile involves a change in density of the material of the crust throughout the sixty miles of thickness of less than 2 per cent. Surely this is not a very large change of density, and it might well be caused by some change of physical or chemical state due to changed temperature and pressure brought about by denudation and sedimentation.

The earth's crust must be very weak to permit the isostatic condition to be maintained so perfectly. Thousands of earthquakes occurring every year indicate that rock is being broken under stress and strain. It is difficult to see how the earth's crust can at one place be under tremendous horizontal compressive stresses resulting in an uplift and not far away be subjected to horizontal tensional stresses resulting in a depression. As a matter of fact, uplift and sinking are going on at the same time in the earth's crust, for where a mountain area is being formed in a region that was previously subjected to heavy sedimentation a trough is being formed where the mountains once stood that furnished the sediments now being uplifted. Surely the earth's crust as a single unit can not at the same time be subjected to both compressive and tensional horizontal strains world-wide in extent.

Relation of Gravity Anomalies to Geological Structure

When the gravity data are corrected for the effects of topography and compensation and the anomalies are obtained this information can be applied to certain geological problems. It has been found that the isostatic gravity anomalies in general are due to abnormal densities close to the gravity stations both horizontally and vertically. Where stations are placed close together around a disturbed area the space occupied by abnormally light or heavy material can be outlined in a general way.

There are several instances in the United States where the gravity anomalies and the geological structure seem to be in complete accord. A notable example is the eastern margin of Puget Sound. Thirty or more years ago a station was established at Seattle and the anomaly, or unexplained difference between the observed and theoretical value of gravity, was found to be ninety-three parts in a million, which corresponds to the attraction of a disk of surface rock of indefinite horizontal extent and about 2,800 feet in thickness. The block of the earth's crust under Seattle seemed to have a deficiency of mass equal to that amount. The opponents of isostasy some years ago made much of this large Seattle anomaly, claiming that it indicated that the northwestern part of the United States is abnormally light. When additional gravity stations were established in the Puget Sound region, however, the data secured showed very clearly that there is a narrow strip running north and south along the eastern

margin of Puget Sound in which the gravity anomalies are all negative and rather large in amount. On the western margin of the sound the gravity anomalies are practically zero or normal. In a comparatively short distance east of Puget Sound the gravity anomalies become very much reduced in size. All this indicates that there is a deep trough filled with recent material running along the Puget Sound region. This deduction is substantiated by the opinions of geologists that there is a vast amount of recent sedimentary material along the eastern margin of the sound. The data do not indicate, therefore, any decided departure of the earth's crust from the isostatic condition in the Seattle region.

There is a large gravity anomaly at Minneapolis, Minnesota, at a station which for several years stood alone, with no others within about two hundred miles of it. The large anomaly, fifty-nine parts in a million, seemed to indicate that the region around Minneapolis is too heavy and therefore out of balance with the rest of the earth's crust. Later several gravity stations were located around Minneapolis, and these did not show large positive anomalies. In fact one of them at Baldwin, forty miles to the eastward, has a large negative anomaly. Several years afterwards a well was sunk in the vicinity of Minneapolis and at a comparatively shallow depth a ledge of very heavy rock was discovered. At Baldwin the geological evidence seems to indicate the presence of a large body of recent sedimentary material. There are many cases where gravity stations placed close together indicate buried structure. Therefore it would seem possible to depend on gravity observations in reconnaissance surveys made to disclose at least the major features of buried structure. In this way gravity observations have a value in both economic and theoretical geology.

There is much more that could be said in regard to the importance of keeping isostasy constantly in mind when one tries to solve the great structural and dynamic problems of geology. Much has already been written on the subject, and the literature of the future will undoubtedly treat isostasy at even greater lengths than has been the case in the past.

HUMAN BIOLOGY

By EDWIN R. EMBREE

PRESIDENT OF THE JULIUS ROSENWALD FUND, CHICAGO, ILLINOIS

As I read the twenty-seven manuscripts which together went to make up the volume "Human Biology and Racial Welfare," I found myself thinking of Clarence Day's essay which he entitled "This Simian World." He considered what kind of a planet this might be if some other species than the great apes had evolved into mastery. What dignity and wisdom might have been displayed if children of elephants instead of monkey-like animals had developed into leadership; what cleanness and cunning in a world ruled by super-cats; what poise and wisdom in the glorified descendants of eagles! But as a matter of fact, animals akin to monkeys were the ones who did evolve; it is the children of that race who rule the earth today. The biology derived from this ancestry governs our potential development and marks its ultimate borders.

We inherit some very great liabilities from these animal forebears. Our bodies are weak and puny as compared with the magnificence of elephants. The grace and beauty of the great cats is lacking in our simian civilization. We have little sense of personal dignity and no real regard for privacy. We congregate in hordes, live together crowded into tenements and hotels. We are unstable, constantly running after new toys and new ideas, rushing, often aimlessly, up and down the earth as our ancestors used to scuttle chattering among the trees.

But we inherited in common with our monkey cousins one great talent, namely, curiosity. And that single quality, probably more than all other things taken together, is responsible for the phenomenal progress of our race. We have an insatiable hunger to know all about everything. This appetite drives us to avid gossip about our fellows; to handling and tinkering with—"monkeying with"—every object or idea that crosses our path; to rushing hither and yon to glimpse a dog fight or view an aeroplane, and also to deep and profound study of intricate problems of medicine and physics.

Two other characteristics have helped us humans in our special type of progress. Our chattering forefathers have given us a love of talk. We are forever gabbling; we have invented great systems of language; we even pay men to talk to us in groups. We build huge temples called libraries in which to hoard this preserved chatter. We compel children to devote years to the study of talk of previous generations. We have invented devices whereby we can speak to our friends thousands of miles away, and machines which record our babble and reproduce it. This ability to talk and our devotion to it is a biological character of our species. It enables us to communicate ideas as well as gossip and to pass on to the whole race our accumulated research and experience.

We have also inherited a compulsion to action. We must always be busy; we rush about; we build and tear down and build again. We are not content simply to inquire and find out everything, but we are driven to do something about it all. This, again, while it means a lot of aimless motion, also results, for example, in turning our knowledge of physics into bridges and steam trains and aeroplanes, and our knowledge of chemistry and medicine into protection of health.

The twenty-seven collaborators have themselves provided evidence in support of Day's thesis. Each of them is a distinguished investigator, driven by a

"'satiable curtiosity" for facts and explanations. Then having made their explorations they must tell of them; and in the telling they disclose their interest in the application of their facts and theories. Fortunately the desire to tell is strong, and it has led them to write far more easily and entertainingly than is common in scientific treatises. Fortunately, too, their desire to write popularly has not outweighed a painstaking regard for the facts.

What these twenty-seven men of science have joined to tell us is the kind of world we live in, the kind of creatures we are, the probable limits of our future development and the extent to which the human race, by its own effort, can hope to change the world of to-day into a more desirable world to-morrow.

It is important that in such fundamental matters we proceed, wisely, cautiously and on the basis of well-established facts. Any constructive activity in human biology must rest upon the carefully assembled findings of wise research and must be supported by intelligent public opinion. Monkeying with the universe is risky business on any other terms. Indeed, in many minds, the danger outweighs all other considerations. Though human progress has been a series of triumphs over natural forces, certain people can be counted upon to cry out against any new proposal, however well founded upon fact and however carefully considered. They call these proposals "perversions of nature." Of course they are. Man rules and always has ruled by bending the world to his will.

Man rules, in so far as he does, because he has turned nature to his service. Natural science is a series of victories over other animals and over inanimate forces. Coal, in the normal "state of nature," lies in deep pockets underground; electricity naturally is jumping haphazard about the universe. Man has lured the bees to store up great piles of sweet food, not for themselves, but for man. Cows, that by nature furnish milk for their young, he has perverted into continuing their supply of milk long past the needs of their calves. He has exploited the seed-bearing nature of fruits and grains. He has crossed one species with another and produced such hybrid foods as the tangelo grapefruit. He has developed to a state of perversion the normal tendencies of many vegetables so that larger, richer roots grow on Burbank potatoes, more profuse grain on many varieties of wheat and oats, larger and more succulent stalks on sugar-cane. He has interfered with the natural reproduction of animals in order to breed cattle with greater quantities of muscle for him to eat, and hens with a penchant for laying eggs. He has produced abnormalities such as oxen and mules where these better serve some special purpose of his.

Man also interferes with nature when he kills parasites which might otherwise cause his illness or death. He changes natural processes when he gives anesthetics to deaden pain and when he aids childbirth. The whole story of medicine is a history of triumphs over natural forces. And now man is beginning to take an interest in even more vital elements of control. He practices birth control; he makes it impossible for certain of the insane or feeble-minded to reproduce their kind. He is beginning to inquire about the possibilities of breeding not only better horses and dogs, but even a finer race of men. Against such proposals many cry, "It is a perversion of nature." Certainly; but no more so than flying in aeroplanes, using milch cows, growing grapefruit or wiping out the cause of yellow fever.

"Human Biology" is a book for those who dare to look at the world as "biological statesmen." No book could contain all the basic facts and theories, but I know of no other volume which presents so many of them or presents them with greater authority and charm.

RAMÓN Y CAJAL—AN APPRECIATION

By Dr. WILLIAM H. F. ADDISON
THE GRADUATE SCHOOL OF MEDICINE, UNIVERSITY OF PENNSYLVANIA

At the corner of the Paseo de Atocha and the Calle de Alfonso XII in Madrid is the Museo Antropológico, with its pillared portico and domed roof. In front of the *museo* are two statues in stone, one of them of Michael Servetus, who lived in the sixteenth century, and whose history is well known to all physiologists and anatomists. Adjoining the *museo* is a three-story building, not unlike neighboring houses, with arched entryway and balconied windows, and on the third floor is the laboratory of Professor Santiago Ramón y Cajal, the fame of whose researches has extended to all parts of the scientific world. Such are the present surroundings of this great investigator, who has done more than any one else to make clear the cellular structure of the nervous system. The illustration on page 179 is from a photograph taken in the library of the institute in the spring of 1928, while I was studying there. In this room and in the small one adjoining it much of his recent work has been done. The library itself is worthy of special comment. The walls are lined with books on all sides from floor to ceiling. On one of the shelves back of the table where the master sits is a row of books embodying the researches of himself and his pupils. To these he often refers the student for some point in question or topic to be elaborated. The laboratory consists of a series of more or less connected rooms, and here the research workers have their tables and the technicians make the silver preparations. The equipment, both in the way of microscopes and of photomicrographic apparatus, is modern, mostly German or French, and the chemicals used are of the best. There is a feeling of optimism and cheerfulness in the air, as if past achievements were the best augury for future successes.

The wide-spread influence of this Spanish school of neurohistology may be readily gauged by looking into books of histology, anatomy or physiology, and seeing the number of illustrations credited to Cajal.

Cajal's most comprehensive work is his "Textura del sistema nerviosa del hombre y de los vertebrados," published in 1899–1904. This was translated into French by Dr. Azoulay and published by Maloine et Cie. in Paris in two volumes in 1909–11. In this book he gives the results of his personal researches on the histology of all parts of the nervous system. One of the collateral factors in the success of the comprehensive survey which he was able to make was his choice of animal for his work. He made great use of the mouse, one of the smallest of mammals, and by using the young of this form as well as of other forms he was able to follow through all the structures of the brain in a comparatively small number of microscopic sections. Also, because of the contiguity of the various nuclei, he could often see nerve processes extending to their destination. Thus he was able to see the architecture of the mammalian brain in a way nobody had been able to see it before. Following him, many have investigated special parts of the brain, and time and again have found themselves merely elaborating what Professor Cajal had already observed.

Early in life the young Cajal showed a decided taste for drawing. Indeed, he would have liked to become an artist and devote himself to art alone. And so, when he began to study osteology and

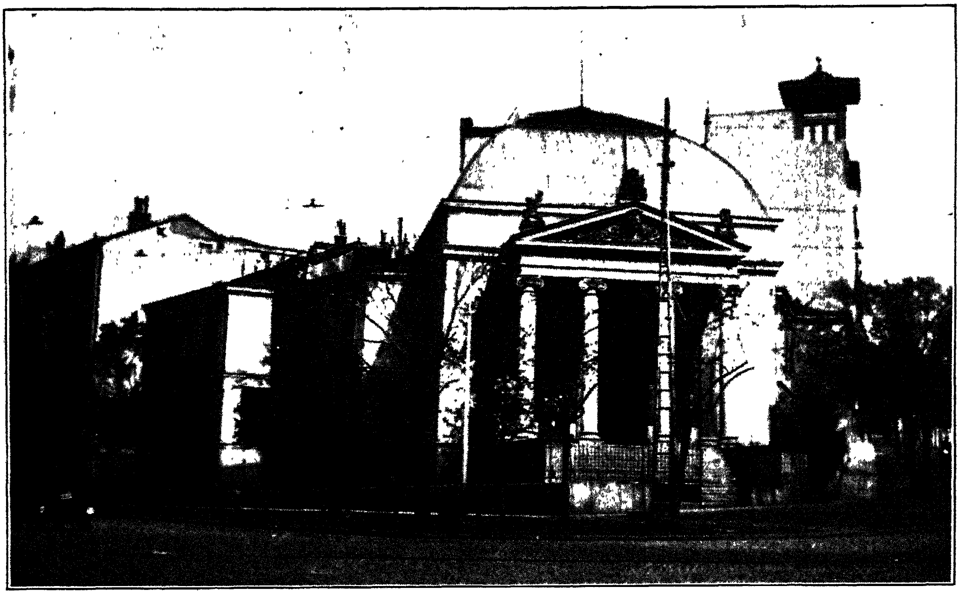
PROFESSOR RAMÓN Y CAJAL IN THE LIBRARY OF THE INSTITUTO CAJAL

later to examine his microscopic preparations, he was able to make fine drawings, and to this capacity for illustrating his own papers must be ascribed some of his success in making the world realize his discoveries. Always there is boldness of delineation, with delicacy of detail, which bespeaks clarity of vision and well-considered judgment.

Professor Cajal has provided us with a delightfully intimate account of his career in an autobiography entitled "Recuerdos de mi vida," the third edition of which was published by Juan Pueyo, Luna 29, Madrid, in 1923. Here he gives us in vivid fashion the events of his early life, his education, his military training in Cuba, his aspirations and enthusiasms, and also a good account of his achievements. Certain parts of the opening chapters of this have been arranged as a reading text in Spanish for the use of American college students, and published by Henry Holt in 1925. The best introduction to Cajal's work is to study this survey which he himself has given us. In more than one hundred full-page plates, he shows us in chronological order the results of his numerous studies.

One of the earliest subjects was the structure of the cerebellar cortex, and to this he has repeatedly returned. His first study of it yielded important discoveries, and he then elucidated for the first time the internal structure of the cerebellum. He was able to see (1888, 1890) the endings of the nerve fibers bringing impulses into the cerebellar cortex. These he designated by the descriptive terms of climbing and mossy fibers, and as a result of this discovery he was able to portray the pathway of nerve impulses through the cerebellar cortex, and the schema which he constructed you will see copied to the present day in practically all books treating of this topic.

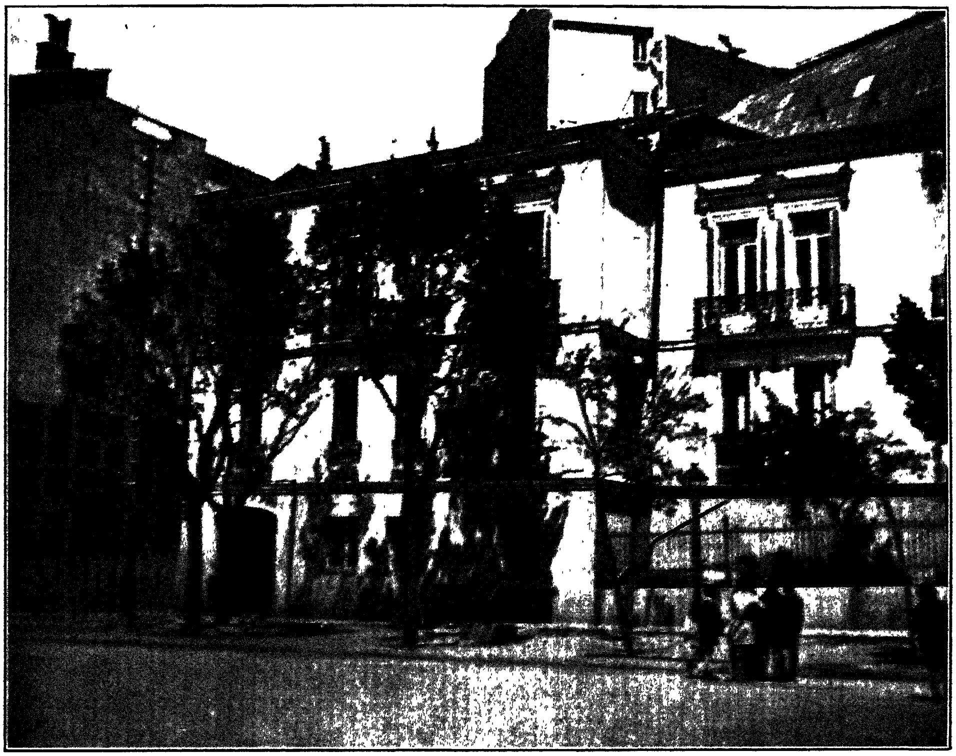
In 1889 Cajal attended the October meeting of the Deutsche Anatomische



MUSEO ANTROPOLÓGICO, MADRID
IN THE BUILDING ADJOINING IT ON THE LEFT IS THE INSTITUTO CAJAL.

Gesellschaft in Berlin. On his journey, he visited Frankfurt-am-Main, among other scientific centers, and there met Weigert and Edinger, of the Neurologisches Institut, as well as Paul Ehrlich. At Berlin he demonstrated his preparations of cerebellum, retina and spinal cord to the assembled anatomists. Among these were His, Schwalbe, Retzius, Waldeyer and Koelliker. There were beautiful preparations of axones of granule cells of the cerebellum, pericellular baskets, climbing and mossy fibers, the bifurcations and ascending and descending branches of the sensory spinal roots, the long and short collaterals of the tracts of the white substance, the terminations of the retinal fibers in the optic lobes, etc. After this convincing demonstration he received many sincere felicitations. The most interested of all was perhaps Koelliker, the venerable patriarch of German histology. After the demonstration he took charge of Cajal, entertained him at dinner at his hotel, introduced him to many of the most notable German histologists and embryologists and exerted himself to make his stay in the Prussian capital agreeable. Koelliker was especially interested in the minute details of the methods employed, and after the meetings went back to Wurzburg and tried out the methods as used by Cajal. In this way he was able to make successful preparations and to substantiate and uphold Cajal's work. After this a knowledge of Cajal's name and achievements spread rapidly through the scientific world, and it was recognized that a new star had arisen.

An idea of his rapid progress and of the readiness with which the scientific world acclaimed his results may be gained from the record of the many invitations and honors received from foreign countries. In 1894 he was invited to give the Croonian lecture before the Royal Society in London; in 1899 he came to America to take part in the celebration arranged by Clark University to mark the completion of its first ten years; in 1906 he shared with Camillo Golgi one of the Nobel prizes. On each of these occasions he made addresses in which he summarized the results of his recent research, and these give a clear



HOME OF THE INSTITUTO CAJAL

indication of the continued trend of his work.

In 1894, when he was in his forty-second year, he delivered the Croonian lecture of the Royal Society of London. This is a signal honor accorded only to investigators of the first rank. Virchow had been the lecturer of the preceding year, and Koelliker and Retzius on earlier occasions. It was not without some hesitation that he accepted the invitation. However, the cordiality of the secretary of the Royal Society, Michael Foster, and of his host, Charles Sherrington, made the visit pleasant and agreeable. His title was "La fine structure des centres nerveux," and the lecture was printed in full in the *Proceedings* of the Royal Society, volume 55, 1894. A good abstract in English appeared in the *British Medical Journal* at the same time, and also a brief account of Cajal's career. The lecture was given on March 8 at Burlington House, with Sir John Lubbock in the chair. In order to follow the discourse each one in the audience was given a printed abstract of the more important points. By the aid also of photomicrographs and of large colored charts, Cajal was able to demonstrate his observations in a clear and convincing manner. After referring to the newer histological methods, he described the minute anatomy of the cerebral nerve cells, and traced some of the pathways for nerve impulses within the brain, especially of the olfactory and visual systems. He showed how the impulse within a nerve cell passed from dendrites to cell body, and from cell body to axone, introducing the idea of the dynamic polarity of the neurone, which is regarded to-day as a well-established law.

Cambridge University conferred on him the honorary degree of doctor of

science on March 5. The official orator made the presentation address in Latin. In it he referred to the use of gold and silver in unraveling the delicate filaments of the human body, and concluded with a selection, slightly altered, from the Spanish-born Roman poet Martial. All this was highly entertaining to the guest of honor. At the dinner of the Royal Society he was acclaimed with great enthusiasm, and Michael Foster declared in his eloquent discourse that "thanks to the work of Cajal, the impenetrable forest of the nervous system had been converted into a regular and pleasing park." He was showered with all forms of hospitality. Also he was taken about the hospitals and medical schools, and regarded himself as fortunate in seeing physiological experiments in the laboratories of Ferrier, of Horsley and of Mott, and examining the histological preparations of Schaefer and of Sherrington.

In 1899 Cajal was invited to take part in the decennial celebration of the founding of Clark University. He was one of five distinguished Europeans selected to give addresses embodying the results of their own researches. The others were A. Mosso, professor of physiology at Turin; E. Picard, professor of mathematics at the Collège de France; A. Forel, of the University of Zurich, and L. Boltzmann, professor of theoretical physics at the University of Vienna. He arrived in New York at the beginning of July and found the heat suffocating, much hotter than Madrid, and the heat pursued him into New England. At the celebration he gave three discourses on "The Comparative Study of the Sensory Areas of the Human Cortex," a topic on which he had been working during the years 1898 and 1899. In the audience, he tells us, there were chiefly physicians, naturalists and psychologists. The lectures were illustrated by large wall charts done in colors, and to those especially interested in neurological technique he gave a demonstration of his microscopic preparations. Cajal's lectures were delivered in French, but were translated for publication, and they together with the other lectures and the proceedings of the

THE NEW INSTITUTO CAJAL

meetings were printed in a memorial volume—"Clark University, Decennial Celebration," 1899, issued by the university. These lectures of Cajal were illustrated by thirty-one figures, and are important contributions to our knowledge of the subject. His closing paragraph strikes a prophetic note of more than passing interest:

> I can not conclude this, my third and last lecture, without a word of tribute to this great people of North America—the home of freedom and tolerance—this daring race whose positive and practical intelligence, entirely freed from the heavy burdens of tradition and the prejudices of the schools which still weigh so heavily on the minds of Europe, seems to be wonderfully endowed to triumph in the arena of scientific research, as it has many times triumphed in the great struggles of industrial and commercial competition.

After the meeting he visited the educational institutions of Boston and New York, and also took a trip to Niagara Falls. He saw much to interest him, and has written in the "Recuerdos" an entertaining account of his impressions of life in America.

In 1900 the International Congress of Medicine, meeting in Paris, awarded him the Moscow prize. This was given for those medical achievements, published within the preceding three years, which had rendered the greatest service to science and humanity. This was direct testimony to the high place he already occupied, not only in laboratory but also in clinical science.

Perhaps the greatest international honor attainable is to receive the Nobel prize. In 1906 the prize in physiology and medicine was divided between Santiago Ramón y Cajal, of Madrid, and Camillo Golgi, of Pavia. On December 12, 1906, Cajal delivered his address at Stockholm on "Structures et connexions des neurones." On the preceding day Golgi had given his address, "La doctrine du neurone, théorie et faits." Already, on December 10, the king had presented the prizes to the several recipients in the presence of the royal family, the diplomatic corps and a distinguished gathering of literary and scientific men. His introducer said that Cajal by his numerous discoveries had given to the science of the nervous system the form which was accepted at the present time, and that by his researches he had laid the foundation on which would be built the future developments of this branch of science. At the banquet Professor Sundberg proposed an enthusiastic toast to Professor Cajal. Cajal responded, also in French, and recalled among other things the memory of his illustrious predecessors, the pioneers in the science of histology.

Each time Cajal was called away from his laboratory he received high honor, and now he had achieved the pinnacle of scientific recognition. But his life work was only well begun. He was already having success with his new methods of reduced silver for demonstrating the neurofibrils within the neurones, and from these he advanced into new methods for showing the structure of the neuroglia more definitely. In the application of these methods he was aided by his students, who exhibited the same enthusiasm as the master. As a result, the Spanish school of neurohistology has contributed as much to the knowledge of the neuroglia as of the neurones.

Madrid has already honored herself in erecting a statue of Cajal. As one walks in the *retiro*, it is with surprise and pleasure that one recognizes the features of the master. In bas-relief on either side are symbolic figures of birth and death, which with the adjoining fountains make an impressive setting.

On a height not far from the present institute is a building still under construction which it is hoped will soon be the home of the Instituto Cajal. In the meantime, in that beautiful and historic city of Madrid the present *instituto* is a shrine which all neurologists and workers in medicine are sure to seek.

AERIAL PHOTOGRAPH OF THE MOUNTAINS OF OREGON AND WASHINGTON

THE PROGRESS OF SCIENCE

AERIAL PHOTOGRAPHY BY INFRA-RED RAYS

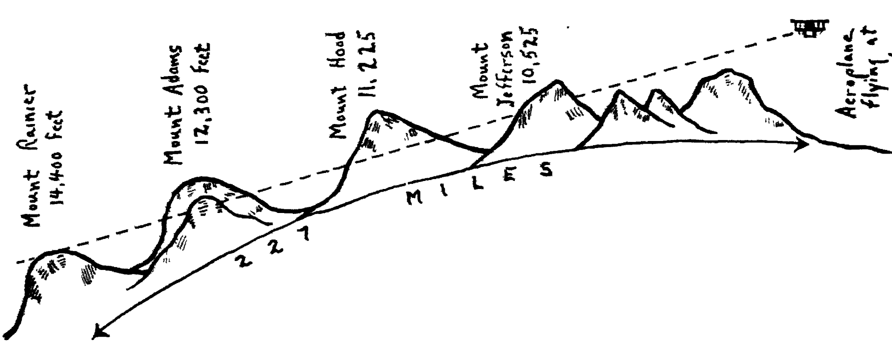
THE accompanying photographs were taken last August by Captain A. W. Stevens, of the U. S. Air Corps, from an airplane flying at an elevation of seventeen thousand feet. Mount Rainier in the state of Washington was 227 miles north, the pictures having been made from a point well south of the center of the state of Oregon. The distant mountains are beyond the range of the eye and are recorded on the photographic plate by the infra-red rays. Even on clear days the atmósphere contains sufficient moisture and dust particles to limit vision, and the infra-red rays penetrate the smoke and haze to a greater extent than the shorter rays of the visible spectrum.

Experts at the Eastman Kodak Research Laboratories have made a thorough study of haze penetration and have found that by using special emulsions and color filters results can be obtained which greatly eliminate the ever present haze factor. Aerial photographs of good quality have been taken on specially sensitized material showing objects which are nearly invisible to the naked eye because of the obscuring haze.

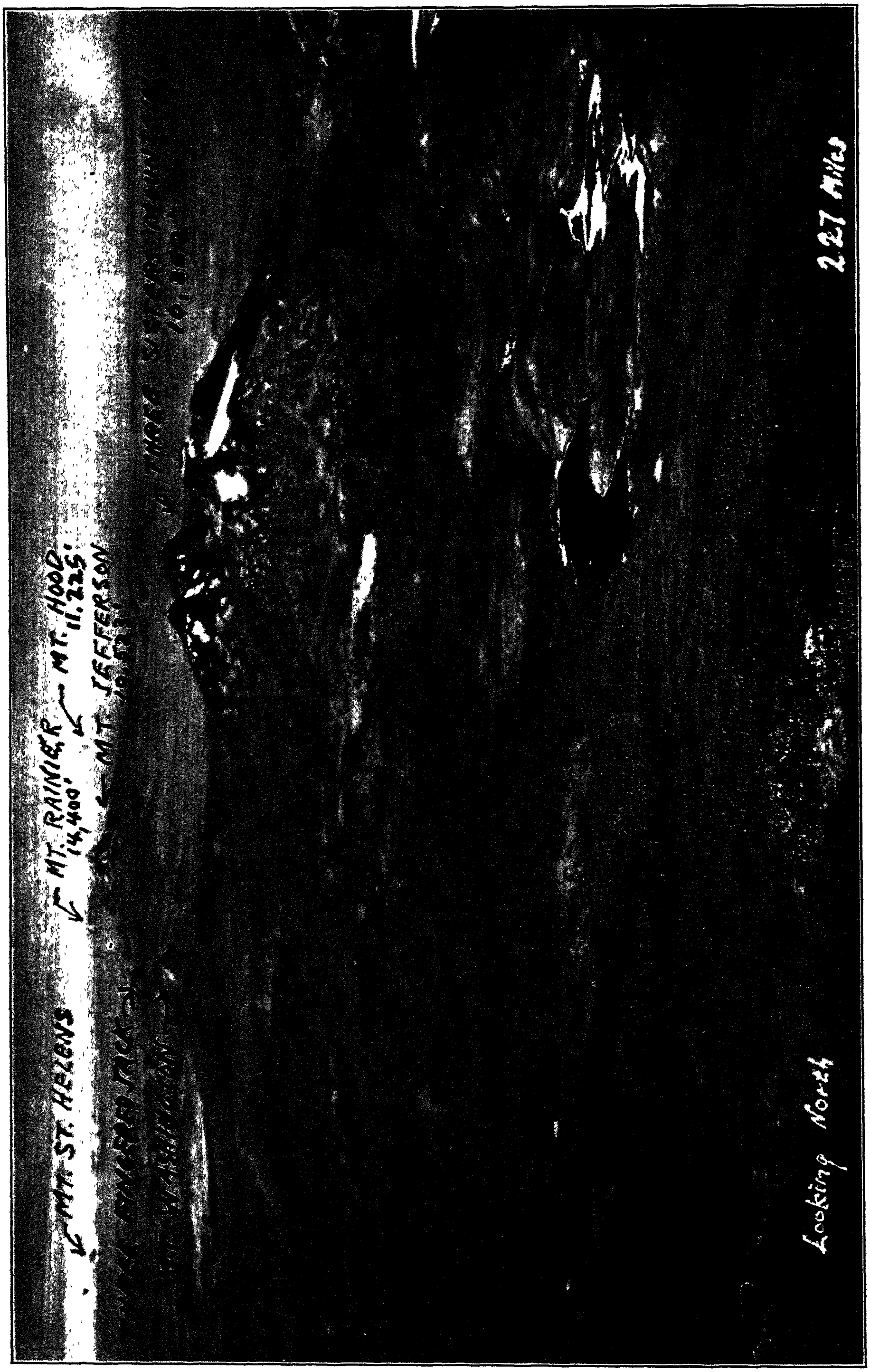
Haze is a phenomenon with which nearly every one is familiar. It is almost always present in the atmosphere to some degree. In taking pictures from high altitudes there necessarily exists a depth of air between the camera and the objective which reflects strong actinic light back to the lens. This light can usually be described as a haze or thin veil of a bluish or violet cast. As the predominating color of haze lies in that part of the spectrum which is most sensitive to ordinary photographic emulsions an emulsion which is sensitive to all visible colors and even to a part of the invisible spectrum, the infra-red, must be used.

A dye called kryptocyanine has been found which will sensitize a photographic emulsion in the infra-red end of the spectrum. Panchromatic emulsion which is sensitive to all colors is bathed with this dye to make it sensitive beyond the visible spectrum.

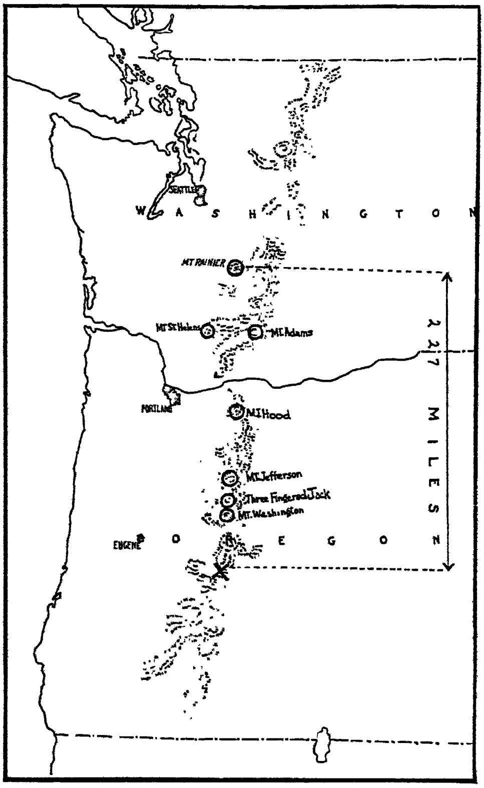
By using a strong yellow filter the violet and bluish light reflected from the haze can be eliminated. This, however, is not all the correction needed. Green foliage on panchromatic film with kryptocyanine added will photograph almost white. A red filter must also be used to tone down the green reflection and render foliage more natural. Thus, by using a film so sensitized and a strong yellow and red filter before the



CONTOUR OF THE EARTH AS PHOTOGRAPHED FROM THE AIRPLANE



AERIAL PHOTOGRAPH SHOWING MT. RAINIER AT A DISTANCE OF 227 MILES



MOUNTAINS OF OREGON AND WASHINGTON SHOWING POSITION OF THE AIRPLANE 227 MILES FROM MT. RAINIER

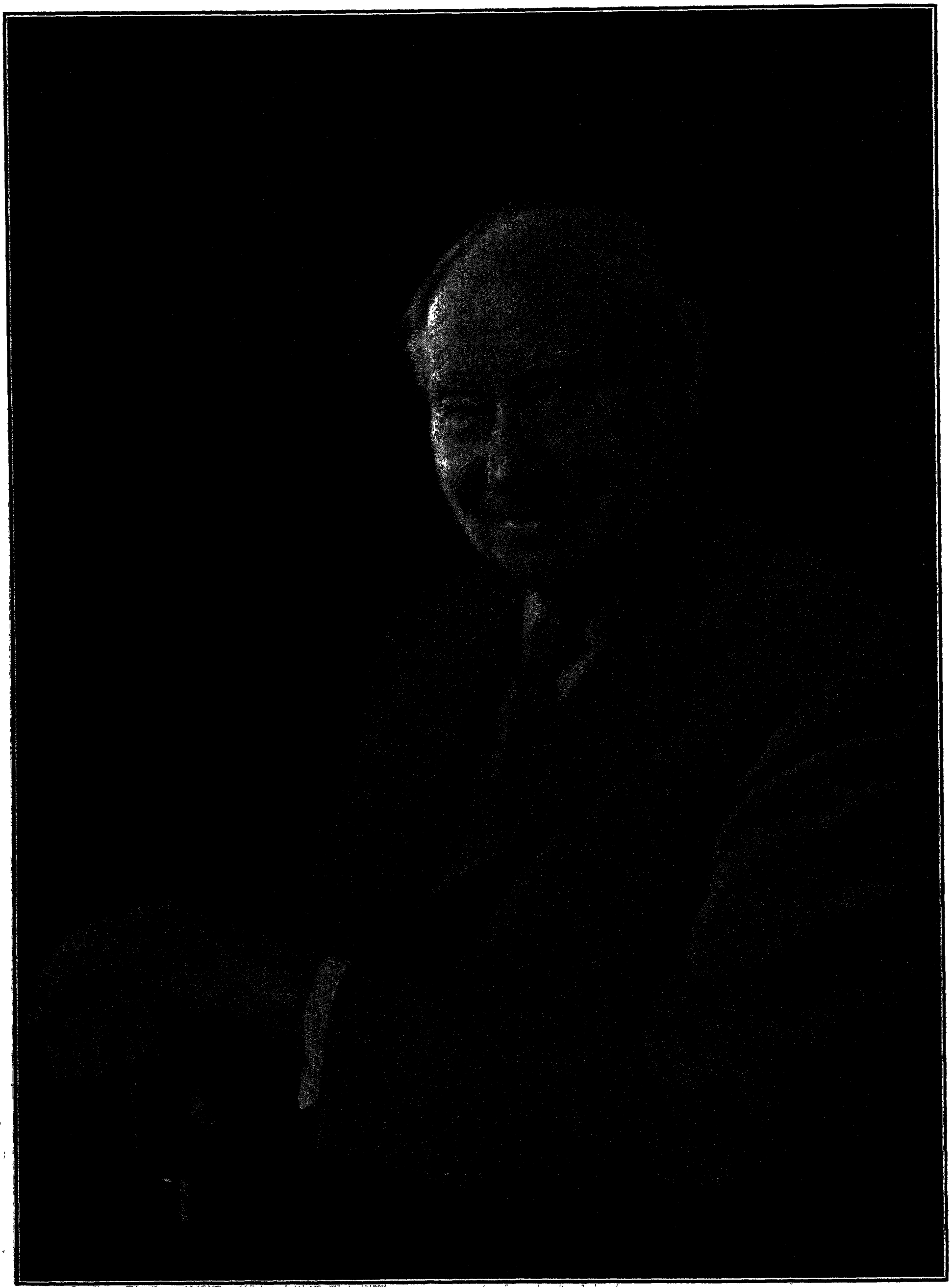
lens, it is as if the emulsion sensitivity started at the farther end of the blue part of the spectrum and gradually increased as it neared the infra-red.

The aerial pictures taken by Captain Stevens were on panchromatic film which had been hyper-sensitized by bathing in a solution of ammonia and made sensitive to the infra-red by the addition of kryptocyanine. Between the components of the 36-inch focal length lens a strong yellow filter has been cemented. This made possible the penetration of the violet bluish atmospheric haze. A red filter corrected the effect produced by the kryptocyanine which renders green too light. This filter will hold back the light reflected from foliage and provide a more natural coloring. Captain Stevens used a time of exposure as short as one thirty-fifth of a second.

There is little likelihood of ever being able to photograph through dense layers of haze since radiation reflected from the haze body is often greater than that reflected from the earth and transmitted by the haze. Therefore when any one speaks of photographing through several miles of mist or fog he is either misapplying the terms "mist" and "fog" to what is usually considered haze, or he is working on the credulity of the general public which has not yet become familiar with the process.

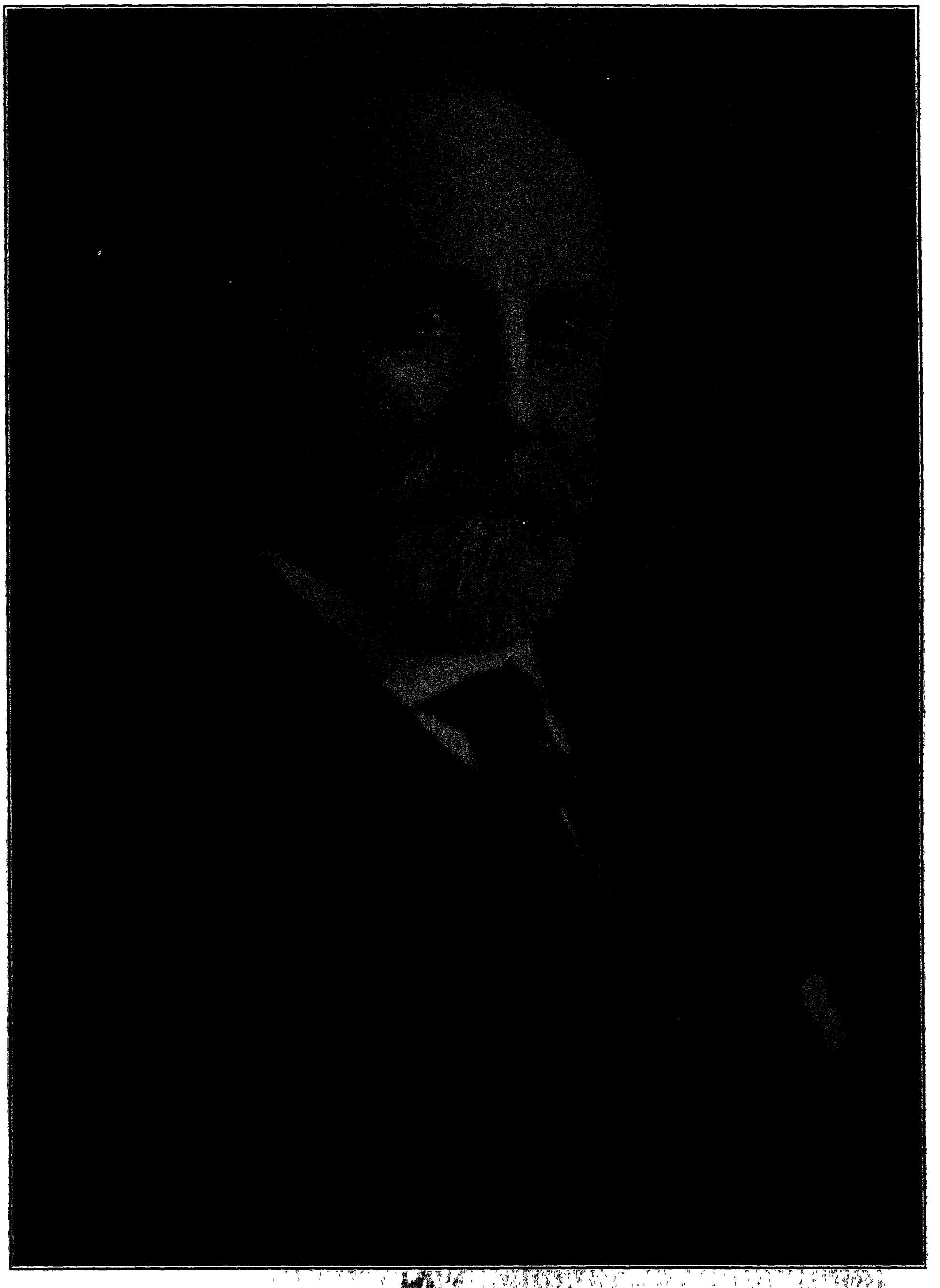
Another interesting adaptation of the use of infra-red photography has been found by astronomers. Dr. W. R. Wright at the Lick Observatory has photographed Mars on ordinary emulsion and with the infra-red emulsion. On the former the planet's atmosphere is clearly visible and on the latter the Martian surface is boldly defined. By superimposing one photograph on the other it is possible to measure the extent of the atmosphere of this planet.

CAPTAIN A. W. STEVENS, U. S. AIR CORPS



DR. HARVEY WASHINGTON WILEY

FROM 1883 TO 1912 CHIEF CHEMIST OF THE U. S. DEPARTMENT OF AGRICULTURE, LEADER IN THE MOVEMENT FOR PURE FOODS AND DRUGS, WHO DIED ON JUNE 30. THE PHOTOGRAPH WAS TAKEN TWO YEARS AGO WHEN DR. WILEY WAS EIGHTY-THREE



J. WALTER FEWKES

LATELY CHIEF OF THE BUREAU OF AMERICAN ETHNOLOGY, DISTINGUISHED FOR HIS CONTRIBUTIONS TO INDIAN ARCHEOLOGY, WHO DIED ON MAY 31, IN HIS EIGHTIETH YEAR

PORTRAIT BUST BY GEORGE LOBER OF DR. EDWARD GOODRICH ACHESON

THE WORK OF DR. EDWARD GOODRICH ACHESON

The United States National Museum has installed an Edward Goodrich Acheson exhibit in its Arts and Industries Building. Rising from the center of a rectangular table is a pedestal on one side of which are grouped a portrait of Dr. Acheson and a number of the medals awarded to him at various times during his career. Below these is a series of three printed labels containing a biographical sketch of Dr. Acheson, and arranged on the floor of the table are mementoes such as his notebook of experiments and scientific observations; business cards and letters when he was associated with Edison; a copy of his paper on "Lightning Arresters" presented before the American Institute of Electrical Engineers in 1889, and his book of tank capacity calculations, compiled and recorded when he was twenty-two years old.

The other three sides of the pedestal and floor of the exhibition case contain material bearing on Dr. Acheson's inventions and discoveries of carborundum, artificial graphite, colloidal graphite and Egyptianized clay. Descriptive labels explain the particular properties of these materials; files containing samples familiarize the visitor with their appearance, and suitable objects indicate their applications to use. The carborundum section of the exhibit includes the original analysis of this substance made by the Pittsburgh Testing Laboratory in 1892; a reproduction of the plumber's pot furnace with which Acheson first produced carborundum; photographs of early and modern electric furnaces; some early carborundum advertising literature, and a few modern carborundum products.

Dr. Acheson was born on March 9, 1856, at Washington, Pennsylvania, where his grandfather, coming from Ireland, settled in 1788. In 1880 he entered the employ of Thomas A. Edison at Menlo Park, New Jersey, as an assistant draftsman under John Kruesi. In July, 1881, he was sent as first assistant engineer of the Edison interests at the Electrical Exposition in Paris. For a time he was connected with the Consolidated Lamp Company of Brooklyn and the Standard Underground Cable Company of Pittsburgh.

Early in 1891, Dr. Acheson produced in the electric furnace the first sample of carborundum, the well-known abrasive and refractory now used all over the world. The invention of carborundum has been of great benefit to many industries, cheapening the production of numerous articles and improving the finish of many others.

Not long after the invention of carborundum Dr. Acheson produced the first large sample of artificial graphite. He took ordinary coke and heated it to extremely high temperatures in his electric furnace which transformed the hard, brittle coke into a soft, unctuous product, graphite. And this graphite he thus produced artificially was better and purer than the natural mineral "plumbago" or "black lead" as natural graphite is commonly called. To-day about twenty million pounds of Acheson graphite are produced annually. Graphite has many uses, among them being lubricants, electrodes and crucibles. The tungsten wire of the incandescent lamp owes its existence to "aquadag," an aqueous lubricant of "deflocculated Acheson graphite." The range of our guns was increased twenty per cent. by surfacing the inner walls with Acheson graphite. The Acheson product is so fine that it will pass through a chemist's filter paper which ordinarily retains the finest precipitate.

Dr. Acheson's career has been fascinating and fertile. Untiring in his zeal and highly skilled in the experimental art, he has transformed into realities, as though by magic, the visions of his active and imaginative mind—realities that are products of inestimable value to science, to the arts and to civilization.

EXPLORATIONS OF THE DEEP SEA

Dr. William Beebe, director of the Department of Tropical Research of the New York Zoological Society, and Mr. Otis Barton have just completed a number of dives in a deep sea chamber or bathysphere in the open ocean to a depth far beyond where any scientific observations at first hand have ever been made. This bathysphere was designed for and financed by Mr. Barton, who in frequent consultation with Dr. Beebe has worked on it for a year. The barge from which the dives were made was kept anchored off Nonsuch Island where the New York Zoological Society Oceanographic Expedition has its headquarters, and the descents were made in the open sea in connection with and within the limits of the area of intensive research which Director Beebe has carried on for two years past.

The length of cable at the greater depths was checked and rechecked both by hydrographic meterwheel and by measuring off and marking one hundred foot lengths of the cable, the difference between these methods being two feet in one thousand four hundred and twenty-six.

On June 6th a descent was made to 803 feet, and on June 11th to 1,426 feet, or beyond a quarter of a mile, with both Beebe and Barton in the bathysphere. The sphere is 57.3 inches in outside diameter and 1½ inches thick, and at the greatest depth withstood a pressure of 652 pounds to the square inch, or a total of 3366.2 tons on the whole surface. Fifteen dives have been made altogether.

The two most surprising phenomena were, first, the abundance of life observed, and the clarity and certainty with which it could be seen and identified, and second, the blue brilliance of the watery light to the naked eye, long after every particle of color had been drained from the spectrum. Another unexpected fact was the presence of fish and invertebrates at these upper levels which, in trawling nets, have been taken only hundreds of fathoms lower. At 700 feet the spectrum, as seen close against the quartz window, was quite devoid of color, the lightest portion being at the 510th wave-length. The last color to disappear was violet, which, many feet above, had completely overlaid the blue.

A strong, electric search-light illuminated the outside water to a distance of many feet, a bag of decayed fish and baited hooks served as a lure, an outside thermometer was easily read, and perfect telephone communication and dictation were carried on without interruption.

Luminous fish and shrimp swam close to the quartz window, about a dozen species of true bathypelagic fish being identified and seen again and again. Puzzling results of the trawling nets were explained, and every possible ecological fact noted and dictated.

A second important phase of the work proved to be dangerous but exceedingly interesting. This was to lower the bathysphere in shallow water, and as the guiding vessel slowly drifted seaward to do contour exploration down the Bermudian insular shelf. The risk was the possibility of suddenly sighting a wall of reef too near to be cleared by reeling the sphere quickly upward. Four such descents, to a maximum of 350 feet, yielded unexpected results, revealing an entirely new fish fauna at these offshore depths and opening a new field for the study of the unknown bottom life connecting the shore with the deep sea faunas. The most notable thing about the recognizable shore fish was their great average size.

The satisfactory margin of safety and the ease and accuracy of observations of fish and other bathypelagic organisms have ensured the advisability of the continued use of the bathysphere for another year.

THE SCIENTIFIC MONTHLY

SEPTEMBER, 1930

MEDICAL SKETCHES IN THE ORIENT[1]

By Dr. ALFRED C. REED

PROFESSOR OF TROPICAL MEDICINE, UNIVERSITY OF CALIFORNIA

Two dominant impressions develop in the mind of one who travels in the Orient with some knowledge of its history and experience of its races. So powerful are these impressions that they seem to throw new light on the problems of disease and sanitation in the Orient, and at the same time to offer a much-needed clue in finding the road to medical improvement. By medical improvement is meant betterment in all that makes for physical, mental and spiritual health. These impressions receive confirmation from each of the great social divisions of the Orient—China, Japan, Malaya and the Pacific Islands, India and the Moslem world.

The first impression is of the deep-rooted Oriental significance of the unity of race and religion. This leads to serious and pregnant situations in government, in business, in the social fabric and in matters of health. Religious ideas become paramount in health programs and in individual care of the sick. Health matters, even more than in the Occident, are influenced by the concerns of business or economics, of education, of social customs and relations which are based chiefly in religion, and, above all, by religion itself. This will be illustrated in the pages following. Unity of racial culture and racial religion gives strength to each, and what affects one draws reaction from the other. This has a paramount bearing on any proposal for medical improvement.

The second impression is of the boundless, largely chaotic but essentially ethnic urge of nationalism. It has almost a biologic quality. It is often ill advised; it may lack leaders who combine vision, rectitude and ability. It may be inchoate in the minds of the population. But it is a seething yeasty brew that is heady, to be sure, but much more is an evidence of the impact of Occidentalism and its individualism on Oriental collectivism. The nationalistic urge has depth and primitive strength. It rises from deeps but little known or understood in the West. Probably it is irrepressible and inevitable. Certainly it is conditioned closely by the first of our impressions, that of the unity of race, culture and religion in the Orient. Out of the interplay of these two great sets of forces—the one unreasoning, somewhat subconscious, instinctive and age-old, the other breeding the germ of intellect, emerging into full consciousness and lately developed—out of this titanic and elemental interplay are to develop conditions and situations which the Western scientist and physician can only view with the most profound interest and sympathy.

No appreciation of the Oriental attitude toward health and disease is possible without at least a slight under-

[1] From the Pacific Institute of Tropical Medicine, San Francisco.

COUNTRY VILLAGE BELOW MADRAS
NOTE RACIAL TYPES IN GROUP OF GIRLS AS SHY AS RABBITS.

standing of the basis of local native psychology. None exalt the individual. All decry the value of human living. All in theory are highly spiritual and intellectual, in practice are sordid and easily descend to magic and superstition. Similar conditions are not unknown in the Western world.

In ancient years in China, so the story runs, the Son of Heaven lay grievously ill, beset by a hundred thousand devils who were fast stealing away his very life. In vain the astrologers, the magicians, the wise men, geomancers and physicians sought to turn the tide. Finally the sick emperor called on the two generals of his army, who had never failed him, to come to his aid. The one entered the sick chamber and said "Hah" in a loud tone of voice and by the blast of his breath slew fifty thousand devils. The other exclaimed "Hoong" in a loud voice, and at the blast of his breath the other fifty thousand were slain and the emperor was restored to health. From that day to this General Hoong and General Hah have been the guardians of the gate of every Chinese household, and the fierce aspects of these gate gods painted on the doors keep out the swarming disease devils of an incautious imagination. All this is not so different from our own mad-stones and saving relics, whether of rabbit-foot or saint.

Not only do the Chinese live under the medical domination of magic and the dragons of air, earth and water, but even now Confucianism is powerful. A large part of the life of China is lived on its waterways. Rivers, canals and oceans bear on their broad waters a population numbering many millions and even yet afford the chief means of transport. The sampan and junk are essential for the life of China. Each of them has, painted on its bow, eyes to

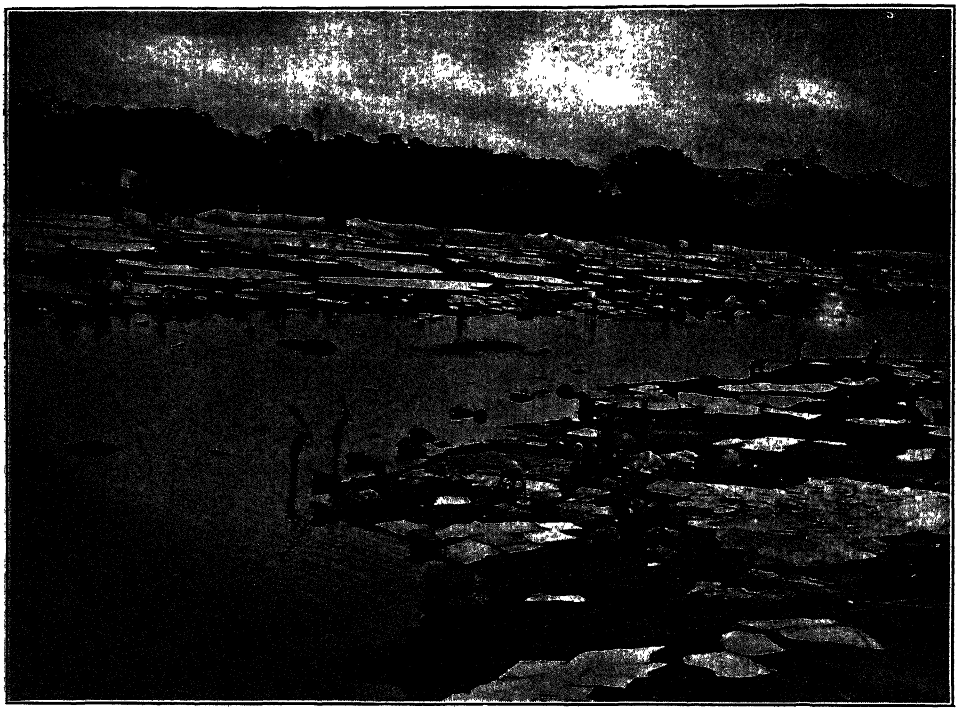
see where it is going—a perfectly logical procedure when every object may be the embodiment of a spirit. Each junk and houseboat is steered by a steersman who sits and faces astern and steers by landmarks he has passed. All China even yet is trying to steer by landmarks in the past because Confucius taught that perfection lay in the past. This tacit system of belief has worked with peculiar force to oppose Western ideas of medicine, sanitation and health. Just as with our religion, so our modern medicine must be studied by the Chinese and then adapted by them to their own needs. Faster it can not go and no other road can prove permanent. Nationalistic growing pains will doubtless continue for a generation or more, and then from the ashes of the old backward-looking middle kingdom will appear, phenix-like, a great Far Western nation, expressing the fine foundation and capability of this great race.

Chinese knowledge of disease in some cases is quite accurate and very ancient. A terrible curse of the Orient and all the tropics is rabies. The fact that many of the native races do not believe in the existence of disease or the reality of disease transfer does not prevent rabies being prevalent. Excellent Pasteur institutes are found in the chief cities from Cairo to Shanghai. In these is manufactured the serum which prevents rabies. It is not a cure, but is a sure preventive. The people know rabies. From the earliest recorded times, the Chinese have associated it with the infected saliva of mad dogs. Dog rabies is rampant. Human rabies is frequently seen because the specific Pasteur treatment is not available or is used too late.

China learned the dangers of smallpox many centuries ago. Inoculation has been practiced since the eleventh century, it being considered that smallpox inoculated into healthy children was less dangerous than when contracted by natural infection. Almost the entire population in some sections is pock-marked. The death-rate is high, the suffering severe and the after-effects are often crippling and invaliding. These facts were discovered by sad experience, and explain the great popularity of vaccination all over China since its introduction in 1805 at Canton by Dr. Alexander Pearson, of the Honorable East India Company.

All over China tuberculosis, especially in the pulmonary form, is nearly universal. Damp, sealed houses and the practice of spitting on the floor are to blame. When cold weather comes, every crevice is sealed with paste and paper strips. Charcoal braziers are the usual form of heating. Carbon monoxide poisoning is common and frequently entire families die. Then it is customary simply to add more garments as cold increases. Cold, damp houses are not conducive to bathing and personal cleanliness. Droplet infection of the air in such houses is very heavy. Not only tuberculosis, but pneumonic plague and influenza are spread with great ease by this means. A complete absence of what we call "sanitary sense" is usually one of the surprises lying in wait for the newcomer to Oriental lands. Transmission of bacterial diseases is entirely beyond comprehension. Social usage includes insanitary procedures such as spitting on the floor, and forbids various Western procedures such as the use of the handkerchief. Education in common-sense automatic disease prevention is distressingly slow, even in our Western countries, and a bare beginning has not yet been made among the masses of Asia.

One great national habit has undoubtedly preserved the Chinese race from destruction by dysenteries and other water-borne infections such as the typhoids. That is the racial addiction to hot tea. Just as the spout of the teapot



MADRAS PUBLIC LAUNDRY
THE STONES STAND THIS LAUNDRY METHOD QUITE WELL.

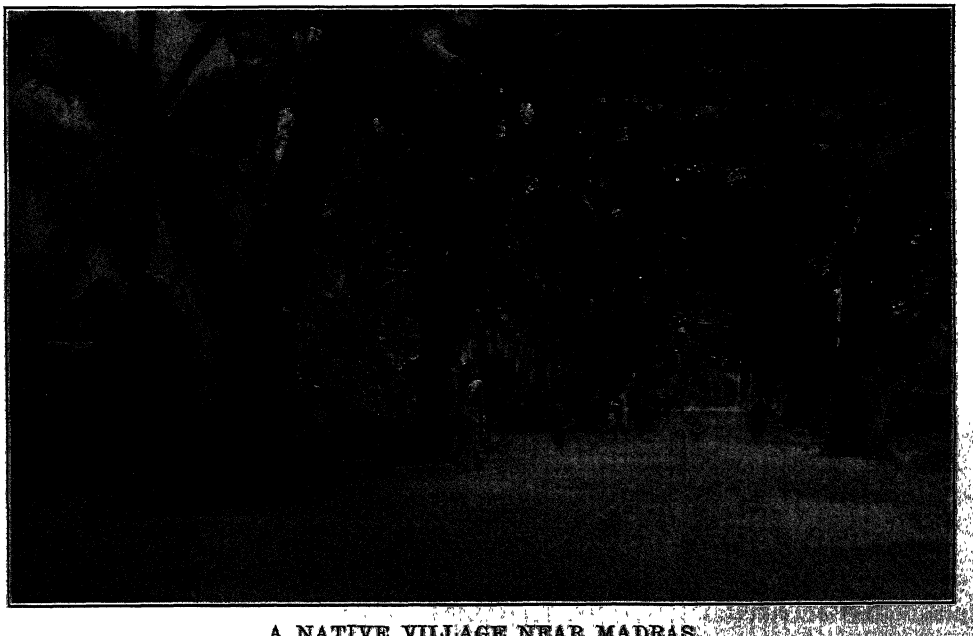
was made to drink from, so the boiling water sterilizes the decoction of tea. But all water in lower Asia is infected and even bathing in it is not safe. Up and down the Yangtze, the warm shallow waters carry the cercarial larvae of the Japanese blood-fluke, and these larvae penetrate the skin of the bather or hunter or chance victim. Foreigners thus contract a serious disease at times. Even the mud is full of risk to bare feet because of the omnipresent hookworm.

In fact all the helminthic host of human parasites flourish luxuriantly in the fertile soil of China which owes its fertility in chief measure to the use of night-soil as fertilizer. The sights and smells of this traffic beset the landscape and offend the senses in city and country alike. By this means, virulent bacteria and numerous parasites are propagated and broadcast over the land. Not only are the farmers and coolies subject to infection but field produce, vegetables, fruit, melons, etc., are all contaminated and carry contagion to those who eat and drink without care for the morrow. Pineapples and watermelons in southern and central China are a great means of spreading cholera germs. The wily farmer sells his melons and cucumbers accurately by weight, having, however, previously punctured the rinds with stiff bristle brushes and soaked them in water, which is always contaminated. Melons are precarious articles of diet in Asia. And yet the use of night-soil as fertilizer is a logical and economic system. In the West, the most valuable form of fixed nitrogen for plant use is entirely wasted by our wasteful conservancy methods. The Chinese method is effective, saving, logical, but unesthetic and disease-breeding.

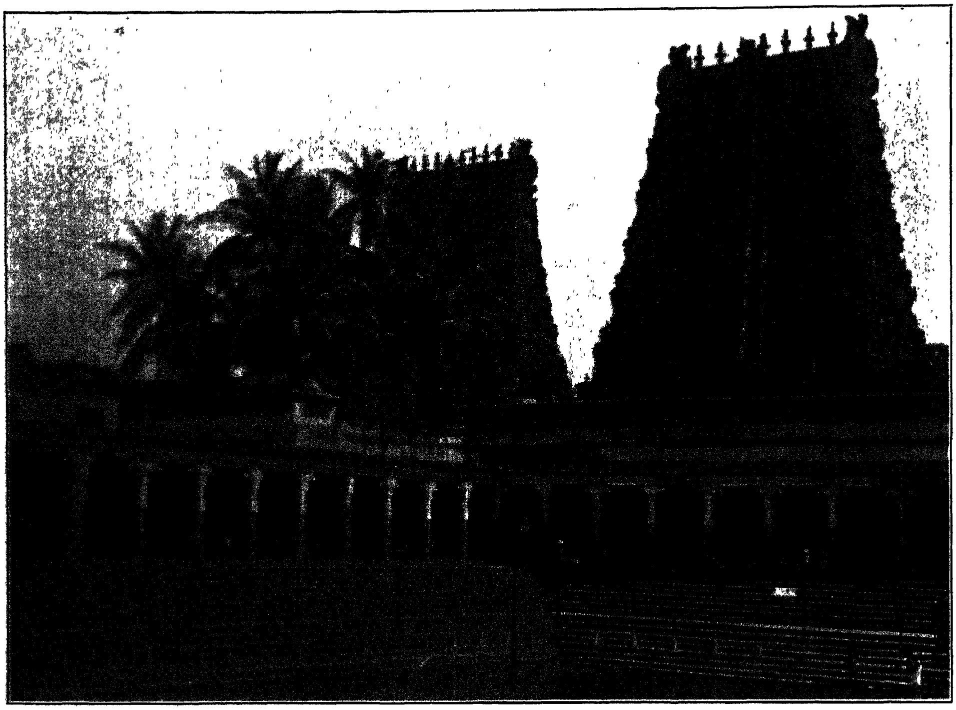
In China one must needs pay tribute to two medical institutions at least. One

of these, with great promise for the future, is the entirely Chinese medical school in Shanghai which is a part of the Nationalist Central University at Nanking, the capital. This school is under the direction of Dr. F. C. Yen, an experienced and skilful administrator, highly trained in Western medicine and with a broad patriotism and unselfish honesty all too rare in this great land so sorely in need of leaders. The other is the fine Peking Union Medical College, which represents the statesmanlike policy of the Rockefeller Foundation.

Southward from China one comes into the rich lands of Malaya. The Malay countries center in the Malay Peninsula, one of the richest and perhaps destined to be one of the most permanent of the British colonies. Around this center are the Dutch islands lying between British Malaya and Australia, French Indo-China between Malaya and Hongkong, the Philippines midway between the great fortresses of Singapore and Hongkong, and the fertile plains of Assam and Burma which make Malaya continuous with British India. Only Siam is left, in the Malay group, owing its insularity to the precarious honor of being a buffer state between land-hungry France and imperial England. The carefully systematized exploitation of the Dutch islands and Indo-China rewards the home countries amazingly, and the medical problems of the countryside are handled efficiently by strong foreign rule over a weak and degenerate populace. Batavia has a splendid medical school close knit with the new and excellent Tropical Institute of Amsterdam. Islam and a derived Buddhism largely divide the native races between them. Siam is the very apotheosis of press-agentry and smiles with no forebodings between her two great military neighbors, France and England. In the Malay Peninsula at Kuala Lumpur, a day's journey north from Singapore, we find the Medical Research Institute, unsurpassed in the world for its scientific importance, strategic location and productiveness. Rangoon has its Shwe Dagon, or Golden Pagoda, second only



A NATIVE VILLAGE NEAR MADRAS



THE LILY POOL
HINDU TEMPLE OF MADURA.

to the Temple of the Tooth in Ceylon in the Buddhist mind for holiness and pilgrimage.

Burma and Assam, even Malaya and parts of India have been cursed with the fever known as kala-azar. This black fever has slain its myriads. But its conquest is even now in progress since medical science has found the cause, the means of transmission and the cure. The causative organism was discovered by Drs. Leishman and Donovan many years ago in India, and after them is named *Leishmania donovani*. Its transmission by sandflies was discovered recently by Napier and his associates at the Calcutta School of Tropical Medicine, and here, too, Sir Leonard Rogers and his successors have established its cure by the intravenous use of tartar emetic. So another great tropical plague has succumbed to the test-tube, the microscope, the guinea-pig and the devotion of medical scientists.

The medical pilgrim must approach India with a fair acquaintance with the history, ethnology and religions of this expansive subcontinent. The story of the East India Company and its unscrupulous mixing of politics, shillings and cannon is just as important as the story of the old native Indian civilization of 1500 B. C. on the southern slopes of the Himalayas. Our medical traveler must know something of the religious pilgrimages of the Orient, of their fanaticism and intolerance of sanitary control, of the hordes who follow them and of the teeming populations from which they come. He must remember that India, which contains Calcutta, the second city of the British Empire in size, is really a land of villages, and that all political, economic and sanitary

measures of necessity are measured to the village unit. He must know of the eighty million Moslems, chiefly in north India, who are bitterly intolerant of the two hundred twenty million Hindus. Of each hundred of the three hundred twenty million inhabitants, sixty-eight are Hindus, twenty-two are Moslems, three are Buddhists, three have tribal religions, one is a Sikh and one is a Christian. Of the remaining two, one is either a Christian or a Buddhist, and the other is probably a Jain, or, less probably, a Parsee, a Jew or a pagan. About 1½ per cent. of the whole population is Christian, and nearly three fifths of these are found in the presidency of Madras (Powell).

The basis of the sanitary sins of India is found in her religions, her poverty and her overpopulation. In fact, the same might be said of the entire Orient. In his readable and reliable book, "The Last Home of Mystery," Colonel E. A. Powell epitomizes the social fabric of the land when he states that the social structure of Hinduism rests on the caste system. The ordinary and oldest classification of castes divides them into the Brahmin or priesthood, the Kshatriyas or nobles and warriors, the Vaisyas, the bourgeois or commercial class, and the Sudras or manual workers. This general idea in fact pervades the Orient, and the Orient has yet to learn the dignity of manual labor and the noxiousness of priestcraft and warriors who parasitize the body of society. The Chinese have corrected the idea by assigning the warrior to the bottom of the list and omitting the priest. But an even more grievous error was achieved because in old China the marks of social culture were found in long finger-nails and corpulence, because these were self-evident separations from physical labor or even exercise. This low valuation of physical exercise and

ENTRANCE TO GREAT HINDU TEMPLE OF MADURA
NOTE SACRED COWS AND PORTICO SUGGESTIVE OF GREECE

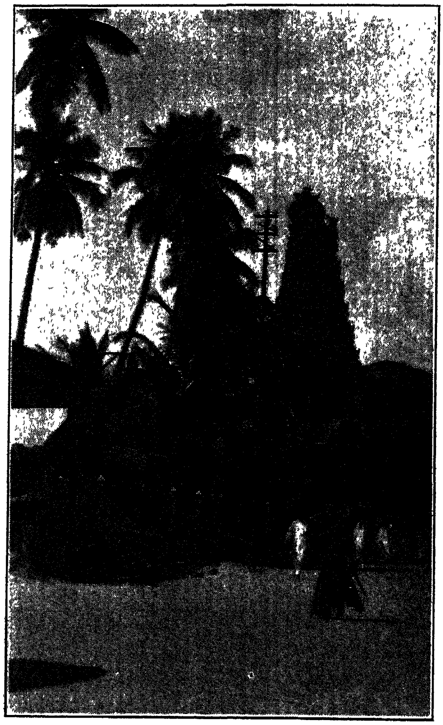
physical development is a sad impediment to personal hygiene in the higher classes of China and, for religious reasons, is an even greater impediment in India.

Returning to the caste system of India, the four chief castes correspond, respectively, to the brain, shoulders, belly and feet of Brahma. There are numberless subcastes, one authority counting 1,429 of them. A quarter of the whole population is represented in the outcastes, such as the Paraiya or pariah, which furnishes all the servants of Europeans.

The religion of Hinduism can best be summarized for our purposes here in the words of two writers. Sir Alfred Lyall said:

> Hinduism is a tangled jungle of disorderly superstitions, ghosts and demons, demigods and deified saints, household gods, tribal gods, local gods, universal gods, with their countless shrines and temples, and the din of their discordant rites, deities who abhor a fly's death and those who still delight in human victims.

HINDU TEMPLE AT MADURA. NOTE PORTICO

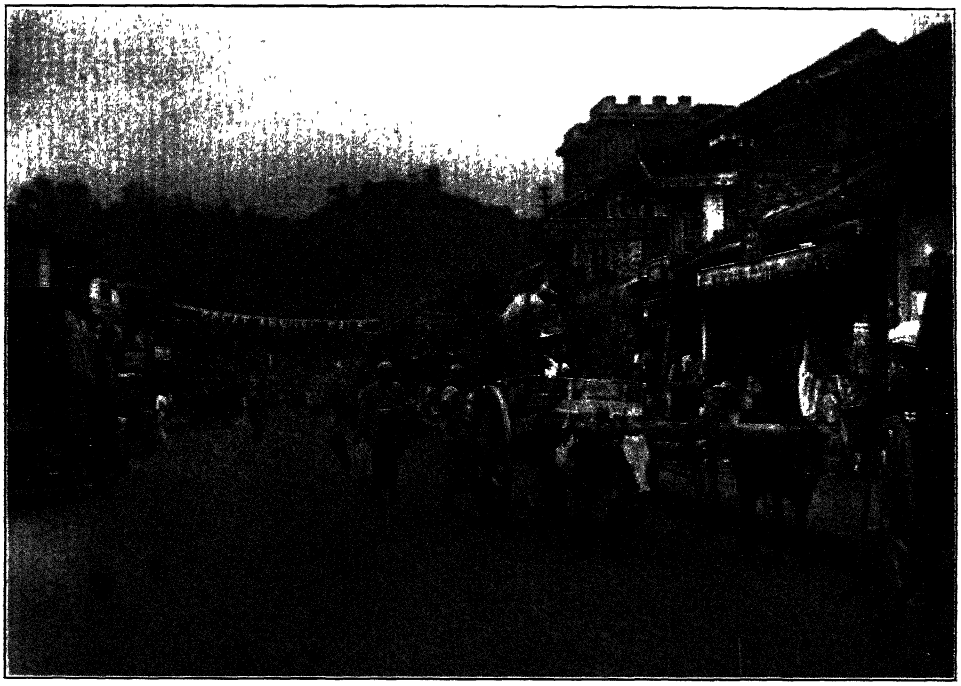


A HINDU TEMPLE OF MADURA

Colonel Powell writes:

> Hinduism is the only religion in the modern world that actually wallows and glories in the unnatural, the degrading and the obscene. . . . However wholesome a faith Hinduism may have been in the beginning, however pure and lofty the conduct, thoughts and aspirations of a certain small fraction of its followers, the undeniable fact remains that it constitutes, on the whole, a spiritual cesspool in whose noxious depths every form of depravity and vice flourishes amid the slime. . . . Until it has utterly exterminated these abominations and all lingering belief in them, Hinduism will remain an unmitigated curse to the vast population which it has spiritually enslaved and debauched.

This is the system, deeply sunk in the depravities and perversions of phallicism, which offers so serious a hindrance to health education and the development of a hygienic conscience in India. Only the abomination of the Tantrik religion of Nepal can conceivably be worse. While "Mother



A STREET IN KANDY

India" does give a partial, distorted and false impression of present-day India, nevertheless the indictment is specific and can not be refuted. "Uncle Sham" may endeavor poorly to muck-rake in our own U. S. We recognize truth in that also, but the facts of child marriage, the caste system, the treatment of animals and the but recently abolished suttee can not be gainsaid as types of what Hinduism has brought to the Indian people. Human sacrifice in fertility rites is an institution old as the human race and has been seen the world over, but Hinduism, in its characteristic devilish fashion, debauches a terrible but magnificent allegory to a grossly sensual superstition.

The ten-acre Hindu temple in Madura, far down in the southern tip of India, is a vast congeries of halls, courts, passages, arcades and rooms, most of which are roofed over solidly. Over each of the ten gates rises a truncated pyramid of stone called a gopuram. These are as high as a ten-story building, and each "story" is a terrace on which are set thousands of images of the Hindu divinities, depicting their lives and loves, passions, vices, families, servants and all the clustering superstition accumulated in the centuries. Outside each gopuram is a colonnade and portico reminiscent of classical Greece. In and out through these portals stream the floods of pilgrims. The climate is hot, the equator is not far off, the children of the poor are naked, the people are burned black by the torrid heat. Inside is a howling, shouting pandemonium, a jostling, crowding mélange of pilgrims, priests, ascetics, holy men, fakirs, beggars, soothsayers, thieves, panderers, children and aged—all mixed up together with sacred animals and birds. From elephants and camels down to the leprous dogs and sleek rats that scuttle about in the semi-darkness, all is filth, vileness and ob-

BANGKOK WATER MARKET
SIAMESE GIRL WITH BETEL-STAINED MOUTH.

scenity. The myriads of shrines and images divide the worshipers among them. The countless butter lamps sputter and glow in the liquid darkness and coat the images with greasy soot. Doubtless no viler sect of men ever trod this earth than the rabble of the Hindu priesthood. They debauch a race and trade on ignorance and fear in order to make an easy living and perpetuate the evil system of which they are the center. The gross obscenity of the images is exceeded only by the teachings and practices of this filthy herd.

In the center of the temple is the Lily Pool, because every Hindu temple must have its sacred pool or tank for the ceremonial ablutions of the devotees. The Lily Pool in this temple is, as usual, the sink into which seeps the sewage of the surrounding district. Every named disease can probably be found among the wretched dupes who bathe and immerse themselves in its yellow polluted waters. Dead animals decay and disintegrate unnoticed. Living animals are too sacred to be killed, but starvation and disease are acts of fate and not to be interfered with. Each man and beast is living out the result of his actions in previous lives. To change the lot of either, therefore, is to interfere with the just apportionment of the gods. Women can hope for betterment only by being reborn as men. Hence they deserve no consideration, being even lower than the beasts.

These crowded dark temples are prolific sources of disease. Moisture, heat and darkness make them ideal culture beds for bacteria, fungi and animal parasites. Ventilation is present only where the British have been able to force the installation of various make-shift air passages in the roofs. These are the holy places of 220 million people. Their lives are bound up in this system. It colors and controls all they do, think, say and hope for. Only a negligible fraction have any conception of the true meanings underneath. Only a pitiful handful can trace the original philosophy so deeply buried in the spume and vicious chicanery of the superstition, fanaticism and ignorance vomited forth by these temples. Verily it makes

the heart grow sick and the imagination pale to confront face to face such a degradation of human possibilities. Sheer pathos is the sentiment inspired by the sincerity and devotion of these milling millions. All phases of medical interest are touched, and the spiritual and intellectual morass has a direct bearing on the physical and psychological evils here rampant.

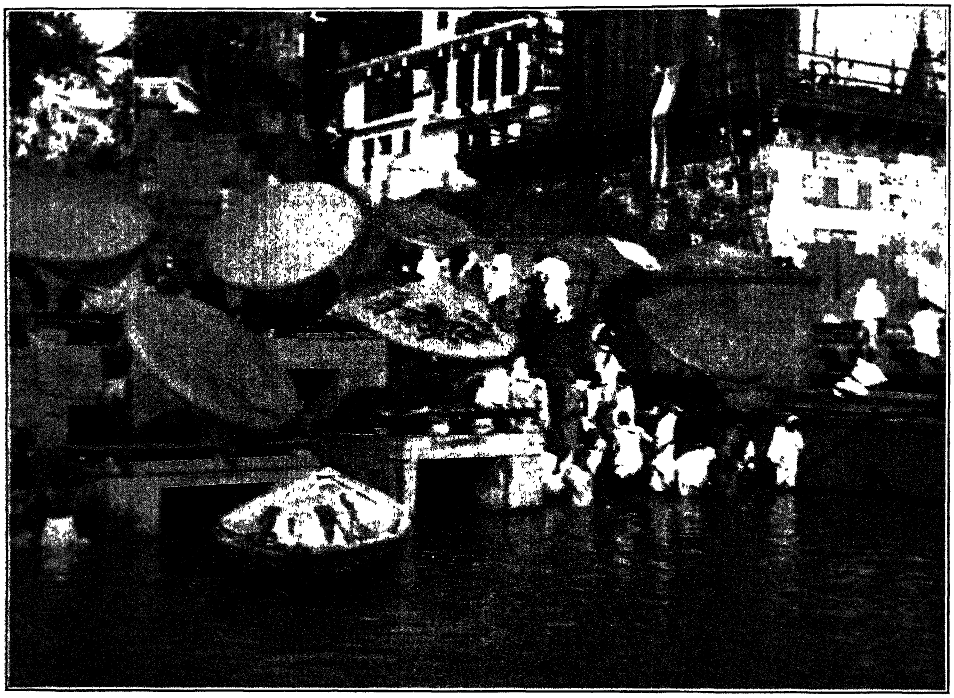
India is too vast, too intricately complex, to be summarized even for medical purposes. A small minority of its people are alive to the needs of the country, are broadly educated, are forward-looking and are unselfishly devoted to improvement. But the predominance is still with the ignorant, fanatical devotees of the great religions of the land. An American can not but be dismayed and chagrined by the number and character of American movies on exhibition. Just as in China and all other Oriental and tropical countries, America is being judged by the trashiest of her cinemas, which are totally misrepresentative and are certain to be highly prejudicial to future international relations, commerce, cultural relations and education. Attention to the character of movie films exported is just as much, if not more needed than attention to immigration and tariff.

At present one does not hear much about drug addiction in India. Opium has been the popular curse of Asia these many centuries. To-day its use is widespread through that continent, but in India opium is overshadowed by another drug group which is a potent cause of mental disease in its devotees. This is the group of drugs derived from Indian hemp. J. E. Dhunjiboy[2] has summarized this subject authoritatively and his data are followed here. The hemp plant was introduced to India from Central Asia as a fiber plant. North of the Himalayas, where it was indigenous, it had presented no narcotic properties, or at least was not used for these. After it was acclimated in India, narcotic properties developed or were discovered, and this led to the first recorded Indian note on the hemp plant in the Atharva Veda. It is now grown and used as a narcotic all over India, and in the Himalayas, Thibet, China and westward through Persia and Syria to Egypt. In cold climates it remains a fiber. In hot climates it becomes a narcotic. It came to India as a fiber. It left India as a narcotic. This exemplifies the common effect of tropical and Oriental residence on human and other immigrants from sterner climates.

Indian hemp (*Cannabis sativa* or *C. indica*) is used in three forms. (*a*) *Ganja* is a mixture of leaves, stems and flowering tops of the female plant. It is smoked in the common water-pipe or hookah, the chilum, the ordinary tobacco pipe and in cigarets. It remains for some follower of the by-paths of human custom to indite a heavy volume on the smoking habits and methods of mankind. Ganja is usually smoked in mixture with tobacco, about three to one. It has an offensive smell and therefore is usually flavored or scented with some one or combination of spices, such as musk, saffron, cloves, cardamoms, rose-leaves or nutmeg. Very often some other powerful drug is added to the mixture, as opium, datura, cocain, nux vomica or aconite. Ganja is also eaten in *pan* (*vide infra*) and sometimes is simply chewed raw.

(*b*) *Bhang* (siddhi, subji or putti) consists of a mixture of the dried leaves and capsules of both male and female plants. It is used as a decoction, as we use coffee, and is the weakest and cheapest of the three drug forms of hemp. The word Bhang refers both to the crude drug and the decoction, or "tea." "Every drinker who can afford it adds

[2] Transac. VII Congress of Far Eastern Assoc. of Trop. Med., 1927, Vol. I, page 400.



BATHING GHAT AT BENARES

some of the following—anise, fennel, coriander, dill, almonds, rose water, cloves, saffron or cardamom. Also, as with ganja, other strong drugs may be added, even opium and arsenic. Bhang is eaten in molasses and in *pan*. Many sweetmeats contain bhang, especially in Majum, which consists of sugar, milk, bhang, and possibly also ganja or charas."

(*c*) *Charas* is the resin exuding from the flowering heads of the female hemp. It is smoked or eaten. It is more powerful, more concentrated and more expensive, which limits its use to the wealthy. This is the hashish of Arabia.

It is a social custom to offer bhang to members of the family and guests on festive occasions, and its use somewhat corresponds to tea-drinking in China and Japan. Ganja is reputed to have been in favorite use by Siva. Hindu priests and people use it in the worship of Siva. Better far if the fiber had been so associated rather than the narcotic! The Sikhs are especially addicted to bhang, and use it in ceremonials on the authority of the Sikh scriptures, the Granth. Charas has no religious associations. Mohammedanism condemns the use of all drugs as well as of alcohol, both prohibitions being widely honored in the breach. In the year 1925–26, the Bengal presidency alone derived a revenue of 48½ lakhs or nearly $2,000,000 from the excise duties on these drugs.

The active principles of hemp are most abundant in charas and least in bhang, but the actual substances have not yet been isolated. In Orientals, a moderate dose causes an intoxication going on to complete drunkenness. A dreamy state with exaggerated flight of ideas often of a sexual nature ends in deep sleep. Some users go through a highly stimulated psychic phase before sleep intervenes. "A large dose causes excitement, delusions, hallucinations, rapid flow of

ideas, ecstasy, psychomotor activity with tendency to wilful damage and violence. This is followed by deep sleep and forgetfulness of all but the initial stages. This temporary amnesia is very important from a medico-legal point of view. The duration of actual amnesia is difficult to judge."

In the fourteenth century in Egypt, Makrizi stated that in year 78 of the Hegira severe laws were passed in Egypt against the use of hemp drugs. Violation was punished by pulling the teeth. In year 799 of the Hegira, hemp addiction was more firmly established than ever. Use of these drugs in any form in large quantities may result in an acute delirious mania which is characterized medically by lack of hereditary influence, by acts of great violence and by a characteristic devil-may-care demeanor. This may go over into a chronic mania where these symptoms are milder, loss of speech for long periods may occur and where the sense of well-being, or euphoria, is prominent. A peculiar congestion of horizontal vessels in the eye (conjunctiva) is diagnostic. A third form of hemp insanity is a dementia. It is peculiar that there are no abstinence symptoms on stopping the drug at any stage and treatment consists simply of drug interdiction.

The hemp drugs strongly predispose to crime. Criminals fortify themselves in this manner, and especially add datura to the hemp. This is at least one cause of "running amok," a violent and dangerous acute insanity common in Malay countries. Hemp drug addiction is more important in India than alcoholism, opium or cocain as a cause of insanity. Hemp is to India what alcohol is to the Occident.

Everywhere in southern Asia is seen the scarlet mouth and spittle of the betel-nut chewer. It is estimated that a tenth of the human race are betel chewers. The name "betel" is used for two different plants. The first is the areca, or betel, palm (*Areca catechu*), a slender, graceful palm reaching a height of forty to fifty feet with a cluster of fanlike leaves at the top. At the origin of

BURNING GHAT AT BENARES

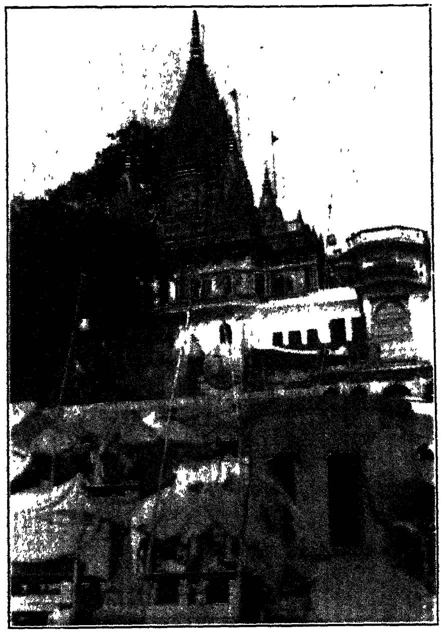
BENARES BATHING GHATS
NOTE TEMPLE SINKING IN MUD, AND UMBRELLAS OF THE BRAHMANS.

these leaves grow the nuts, the size of a hen's egg, looking somewhat like mammoth nutmegs. Inside the tough rind the hard nut is nicely mottled in brown and gray, and is sometimes used for small ornaments and buttons. For chewing purposes, they are picked just before ripening, are husked, boiled in water and shaved into thin slices which are dried and blackened in the sun. These thin slices are rolled in a succulent leaf of the second betel plant, the betel vine or *pan* (*Chavica betel*), which is a cousin of the black pepper plant. With the betel-nut are mixed a little freshly slaked lime, called chunam, and various spices, as in the case of ganja. A copious flow of scarlet saliva results. Apparently cancer of the mouth is somewhat more common in betel chewers. In addition many use zardā, which is an aromatic preparation of tobacco. The use of pan and zarda together destroys the taste so the user may go days without food.

Pan, or tambul, has been used from ancient times from Africa to the Philippines as a digestant, stimulant, aromatic and aphrodisiac. Betel-nut is reputed to be a vermifuge and is the source of the alkaloid arecolin, widely used in veterinary medicine as a worm remover in canines. The betel-nut is also called supari. The native belief is that it hardens the gums, sweetens the breath and increases saliva. It is taken first to cure disease, then to prevent disease and finally as a habit. It is offered to guests as a carminative before and after eating, much as Occidentals proffer mints. Thus with the Hindus and somewhat less with the Moslems, it has become a form of courtesy. All natives use it as an aphrodisiac, and Indian literature, both sacred and profane, has extended commentaries on this usage. S. J. Modi has

shown that the betel chewer suffers definite ill results in loss of sensitiveness of the gums, attrition of the teeth by constant chewing of tough fiber, excessive tartar deposit, recession of gums, pyorrhea and loosening of the teeth. Dental decay is decreased.

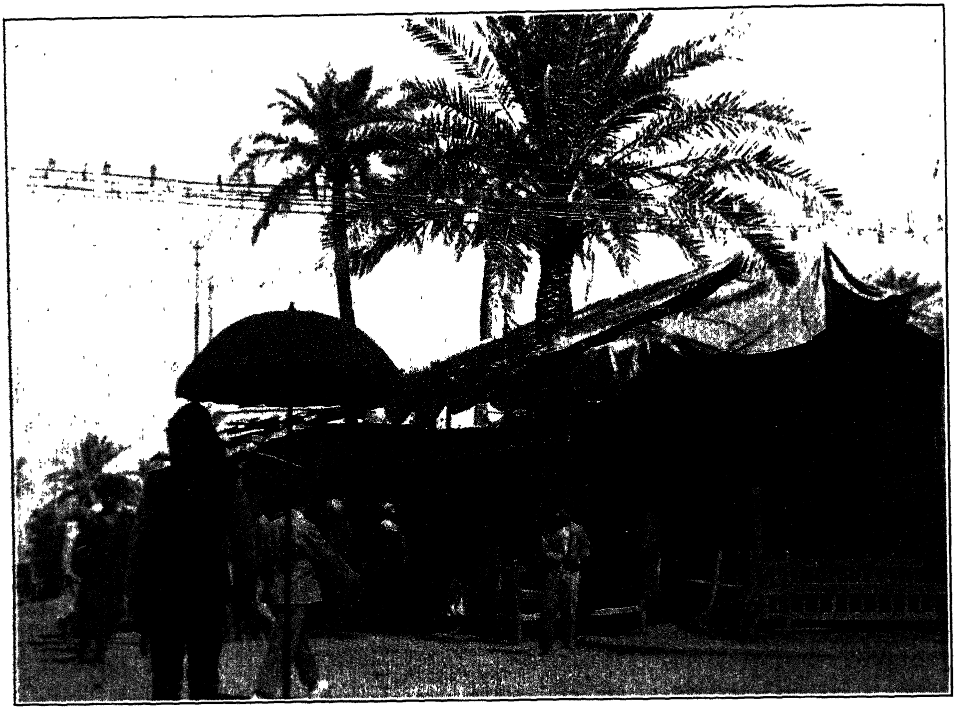
The usual Indian toothbrush, ceremonially required in the case of Hindus, consists of a twig of *Acacia arabica*, the so-called baval stick. This was prescribed in the Ayur-Veda. Other prescribed twigs are used to less extent as, for instance, from the banyan (*Ficus indica*), the Karanja or Indian beech, the neem or margova tree and the pippala or peepul tree. Something must be said for the cleanliness and cheapness of this type of toothbrush. These twigs must be chewed from ten to twenty minutes to form a coarse "brush" at one end. The chewing and coarse fibers packed between the teeth cause damage to the gums and much attrition of the teeth. The Brahman must abstain from washing his teeth on the sixth, eighth, ninth, eleventh, fourteenth and last day of the moon, on the days of new and full moon, on all Tuesdays, on the day of the constellation under which he was born, on the day of the week and of the month which correspond with those of his birth, at an eclipse, at the conjunction of the planets, at the equinoxes, the solstices and other unlucky epochs and also on the anniversary of the death of his father or mother. Such is the life of a Brahman. Certainly tooth-brushing will not burden him, even though he is allowed to substitute grass or leaves for the ceremonial twig on the forbidden days.



THE GHATS AND RIVERSIDE AT BENARES

A FESTIVAL IN A BOMBAY BAZAAR

Few places on the earth are more important than the Ganges River as centers from which epidemics spread. This is due, in the first place, to local conditions which lead to heavy infection of the river and the crowded cities on its banks. In the second place, millions of Hindus visit these localities on pilgrimage and carry contagion back with them broadcast over the country. The sanitary control of pilgrimages is one of the most difficult and delicate problems in the Orient. Crowded, insanitary quarters



TRAFFIC COP ON A BUSY BAGDAD CORNER

for pilgrims, ceremonial bathing and carriage of sacred water back to the villages cause untold disease and death. Similar to this is the situation arising from the desire of all Hindus to be cremated on the banks of the sacred Ganges. As a result, bodies dead of dangerous diseases may be carried for journeys of many days under the hot sun of north India.

The holiness of the Ganges River is concentrated to a superexcellent degree at Benares. This city of 300,000 people may have twice its own population of pilgrims coming and going at once. Its thousand Hindu temples do not have sacred tanks individually but the river is used by all. The pilgrim performs specified rites and ceremonial ablutions in the river before visiting each temple and also as an object of pilgrimage itself. The howling din of the temples with their filthy mud, diseased animals and wild-eyed devotees is more than matched by the crowded ghats of the Holy Mother Gunga, the sacred sewer of the Gangetic plain, which rolls its yellow flood slowly down to the myriad mouths where it joins the Brahmapootra in the Gulf of Bengal.

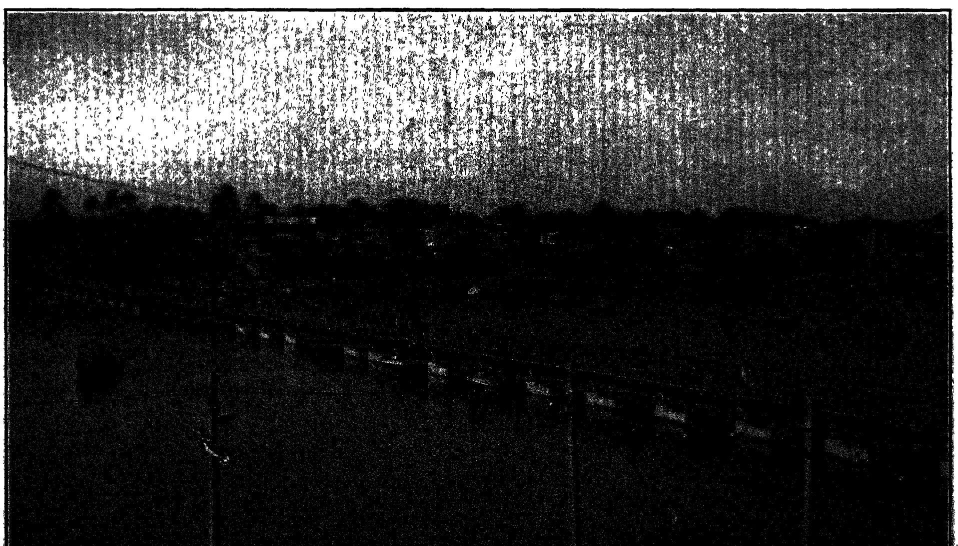
The stone steps, or ghats, leading down the steep river banks are a never-ending panorama of human misery, hope, devotion, fanaticism and gross superstition. Brahmans sit smugly under their wide umbrellas of split bamboo and for a price recite mantrams and prayers and repeat stories from the sacred literature. In the water are crowded the bathers, immersing themselves, washing their mouths, drinking, putting water in eyes, ears and nose, and following the complicated rituals of their faith. Among them the supercilious Moslems are doing their family laundry and bathing for the purpose of "cleanliness." Small children swim, duck and dive among them with many shouts.

The river itself carries along the sewage, dead animals, charred fragments of corpses and general accumulations of a crowded tropical plain. Crocodiles are rarely seen now, possibly having died from overeating. Buildings, temples and palaces are slowly sinking in the alluvial mud and new structures are constantly rising on their disappearing roofs. The maharajas of the native states, 45 per cent. of all India, have their palaces here, to which they will come to spend their last days in the thick odor of sanctity, to be burned on the burning ghats and have their ashes scattered over the broad bosom of Mother Gunga.

A greater contrast can hardly be imagined than to take the overnight journey from Benares down to Calcutta and visit that glory of medical science, the Calcutta School of Tropical Medicine, a splendid, large research building, facing a research hospital of 200 beds. On the same square is the great municipal hospital. An outstanding group of physicians and scientists is gathered here, men whose names carry authority and are known far beyond India. Colonel Acton, the director, Drs. Napier, Knowles, Muir, Chopra, Strickland, with their associates, would make any institution famous. Incidentally, it is interesting to see here in operation a principle destined for wide application in the tropics—refrigeration of rooms and houses comparable to heating of the same in cold climates. Rooms and suites with reduced atmospheric pressure and with controlled cool temperature will be important adjuncts in the treatment of disease in the tropics.

The Calcutta School of Tropical Medicine and Hygiene is a living monument to the faith, ability and persistence of its founder, Sir Leonard Rogers, who has now retired from the Indian Medical Service and is located in London. It was built and is maintained by moneys contributed by planters, shippers and other business men of India with subsidizing aid from government. The business community had found by hard and costly experience that commerce could not be developed or be successful without the aid of scientific medicine. That lesson needs to be learned in these United States.

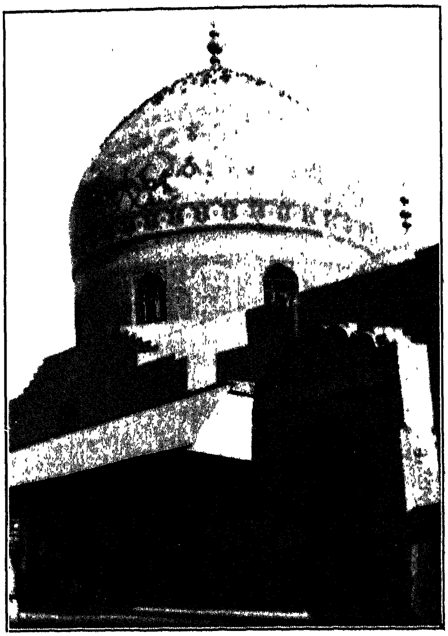
American commerce can not even ex-



MAUDE PONTOON BRIDGE OVER THE TIGRIS AT BAGDAD

ist, in the conditions of competition now developing, unless it utilizes medical science in connection with its marine transport and foreign contacts. American commerce needs several first-class institutes of tropical medicine. It needs them especially in San Francisco, New York and New Orleans, where sailors and shipping are concentrated. France, Italy, Germany, Holland and England know this fact full well, and each of them has institutes of tropical medicine, working hand-in-hand with commerce and government. Hamburg city, the great port of Germany, maintains the finest tropical institution on the continent as part of its city budget. American commerce can well take counsel and warning from these other countries or its path will be costly, difficult and even impossible.

The medical traveler can not but be impressed by several striking facts in the leprosy situation of the world. Once known chiefly in cold and temperate climates, leprosy is now primarily a tropical disease and in some places almost epidemic. Two great facts stand out. One is the hopeful outlook for arrest or even cure of the disease with modern methods of treatment. The other is the



THE LARGEST MOSQUE IN BAGDAD

change in sentiment with reference to quarantine and isolation. Treatment is potent in proportion to the earliness of its employment. Segregation has always meant that chiefly advanced cases and only a percentage of these would be discovered. Sir Leonard Rogers and Dr. Muir, of Calcutta, have stood strongly for a reversal of this policy, establishing ambulatory treatment stations thickly, registering all lepers, spreading healthy information about the disease and as quickly as possible making patients non-contagious. Only dangerous contagious cases are isolated, and then only until rendered non-contagious by treatment. The result is that lepers flock in for treatment in the earliest stages when treatment is most effective. Moreover, they are not withdrawn from industry to be maintained at the expense of government or charity, but remain self-supporting, in hope and usefulness, instead of being immured in the horrible living death of the earlier leprosaria. The work of Muir and

A DESERT STATION ON THE RAILROAD FROM BAGDAD TO BASRA. BEDOUIN WOMAN AND BOY.

BASRA DOCK SCENE
ARAB FAMILIES WAITING TO BOARD THE STEAMER.

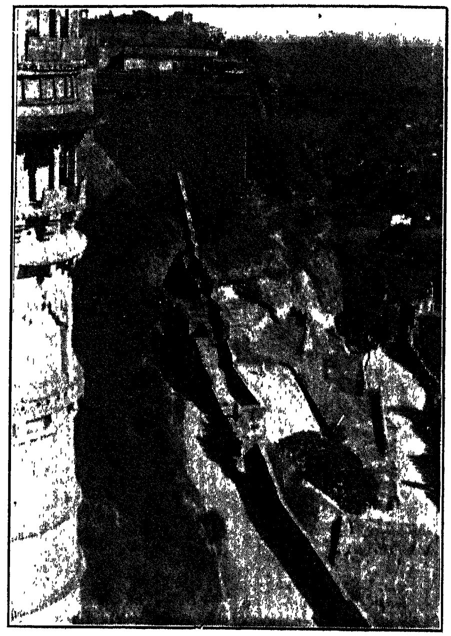
Rogers in Calcutta is noteworthy as is also that of Dr. H. W. Wade and his associates at the great leprosy station of Culion in the Philippines. This latter has now been endowed as the Leonard Wood Memorial, and is a monument indeed to American tropical medicine.

One hardly thinks of India without the mind turning to the subject of snakes. The cobra is closely interwoven with the legend, history and religion of the Hindus. It is sacrosanct, even above other animals, and must not be killed, in fact, is to be worshiped as the sacred Naga. The serpent-lore of India is completely detailed in an erudite volume under this title by Dr. J. P. Vogel. From Egypt to China, the snake has an allegorical usefulness that embodies man's instinctive fear. The ancient ruins of Angkor have the Buddha-like colossi holding the great body of a sacred Naga rearing its seven-headed crest a hundred yards from the narrow, tall elephant gates where the four faces of Siva look down with immemorial and inscrutable calm. In India itself the small true vipers, like the krait, are exceedingly deadly. The cobra family is omnipresent. And in the warm waters of the Indian Ocean and Persian Gulf, the sea-passenger sees multitudes of the brilliant, transversely colored coral snakes, three to four feet in length, like true sea-serpents riding the waves. These snakes never go ashore. They are viviparous and breed at sea. Their bite is deadly, but swimmers are rarely bitten. Water temperatures over 90° F., abundance of sea-food and few enemies make life pleasant for them.

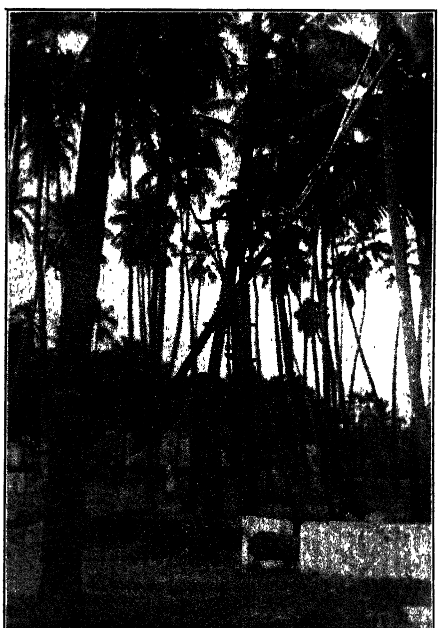
It is probable that half or more of the deaths from snake-bite, in India as well as elsewhere, are due to fright or injudicious treatment. Treatment by tourniquets, free bleeding and the appro-

priate anti-venin is best, and alcohol is an invariable danger. Snakes are deaf and nocturnal. They easily perceive vibration, however. Hence a person walking noisily in leather shoes usually gives enough notice of approach to warn the reptile, which slinks away. Cobras do not flee so readily as other varieties and have even been known to attack without provocation. Walking at dusk or after dark with a lantern and well-booted is the best protection. Usually it is the barefoot native with silent footfall and no light who startles the snake and gets bitten.

The major evils of India, in comparison with Europe, lie in the lower population increase in the face of a higher birth-rate, and a smaller fecundity in spite of a larger proportion of married persons. The population seems to be near the saturation point. The life expectancy is low and sinking lower.



ELEPHANT ROAD UP GWALIOR HILL



PRIMITIVE WELL OF SOUTH INDIA IN COCONUT GROVE

NOTE TWO MEN TWENTY FEET ABOVE THE GROUND WORKING THE WELL-SWEEP.

There is a high death-rate among young mothers. As everywhere, the population increase is higher in the lower classes. Poverty breeds children but can not raise them. As Adam Smith said, "Poverty seems even to be favorable to generation. But poverty, though it does not prevent the generation, is extremely unfavorable to the rearing of children." Artificial limitation of birth-rate is always a debatable expedient, but the same result can be obtained by improvement in economic status and in education. At present, instead of these natural and automatic curbs, India, like China, has war, famine and disease.

All over tropical Asia the experienced traveler carries with him a well-constructed mosquito net, because in many places no net is provided, as in Siam because of local pride, which says there are no mosquitoes of consequence to be feared. A stout flash-light is also valuable, for searching out hiding insects and for various night alarms. Fresh

salads in all Oriental and tropical lands are anathema, and one quickly learns to eat only freshly cooked food. A clean kitchen in charge of a clean cook is rarely found, and simple table precautions save much danger. Various vitamin-deficiency diseases are seen universally, such as different forms of beriberi, pellagra and also the peculiar condition called sprue. Sprue was formerly widespread in Ceylon. Now it is rarely seen there. At the same time deficiency diseases in cattle have decreased along with more intelligent feeding methods, and the foreign human population has changed its dietary habits to include more fresh native foods and less imported canned articles.

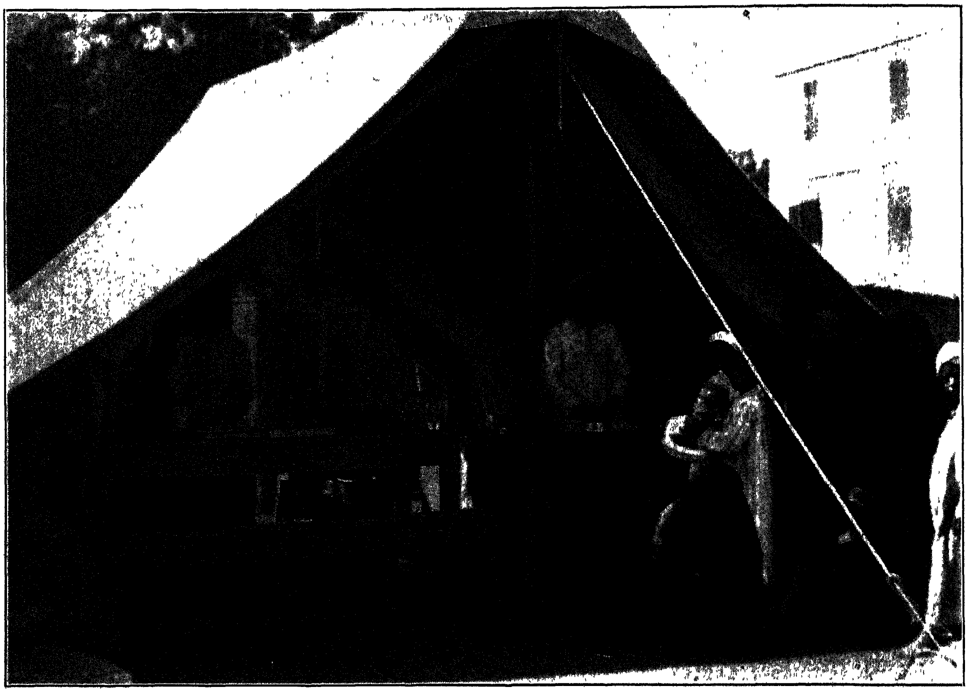
The question of sunstroke, heat-exhaustion or heat disease is of perennial interest. The researches of Dr. Sundstroem at the University of California are opening the way to a much-needed improvement in our understanding of the influence of barometric pressure, temperature, moisture, ventilation and incidence and character of solar radiation. It is probable that the state of one's liver has most to do with the onset of heat disease. Malaria and other infections are easily lighted up. Heat exhaustion is a form of heart failure, induced by climatic conditions in a person predisposed by cardiac weakness or liver congestion.

The tropical world in general has two kinds of climate. One is the moist heat of the equatorial zone, with a maximum of rainfall and cloudiness at the extreme. The other is the dry hot desert zone which borders the wet tropics both north and south of the equator. We see this latter exemplified in the dry plateau regions of our own Southwest and in central Mexico. The same belt in Iraq and Arabia presents many interesting medical situations. Mesopotamia is still a country to swear not only *by* but *at*. Its three million inhabitants are primarily desert dwellers.

From Basra and waystations on the Shatt-el-Arab or mouth of the twin rivers is shipped the bulk of the world's date supply. Here two green strips bordering the rivers are the original home of the date-palm. Over 110 varieties and eighty million trees yield their sticky sweetness to the Arab gatherers, who stamp them bare-footed into burlap sacks, along with flies, vermin, perspiration, excreta, dust and all sorts of just plain dirt. Having seen the date culture in practice, the traveler will carefully restrict his home supply to a product guaranteed to have been produced and packed in southern California.

The old Turkish hospital of Bagdad was taken over by the British and made into an up-to-date and thoroughly efficient modern general hospital. The Turks kept as patients only those who were able to work. The others died or were thrown out. The result was unfortunate medically but has left for the present administration wonderful grounds and gardens with a profusion of trees, shrubs and flowers. Even a small medical school is being started in the effort to train native practitioners to carry the leaven of Western medicine to the tribesmen. Drs. Dunlop, Sinderson, Mills and their associates are working out a fascinating medical program in the old city of the califs. A visit to the Royal Hospital of Bagdad will repay and stimulate any visitor.

The bazaars of Bagdad, Mosul, Aleppo and Damascus are replete with interest for the medical eye. For four thousand years Damascus has been an inhabited city. It has always been the trade center of the desert, and its history is the story of ancient civilizations. Its native medical practice has been little affected by Western science, but Syria boasts of the best medical school in the Near East in the American University of Beirut. Likewise in Syria and Palestine the



LABORATORY TENT
IN TREATMENT STATION IN VILLAGE OF LOWER EGYPT.

places and tales of crusader renown have a singular appeal for the medical wayfarer. The story of the Knights Hospitallers, of the Knights Templars and the Orders of St. John and Jerusalem and Malta bring a wonderful record of medical care and nursing service. The present-day activities of the Hebrew University on Mt. Scopus overlooking Jerusalem, the conquest of malaria in Jerusalem, the control of animal diseases and many another work of health and sanitation need more than the present space even for a catalogue.

The Arabs had an old prophecy that when the waters of the Nile flowed in the streets of Jerusalem and a son of the prophet entered through the Jaffa Gate, then would the Golden City be lost to the power of the Turk, and it so happened that Allenby, the British conqueror, entered the city walking through the Jaffa Gate, and his name in Arabic was "son of the prophet." Also it happened that the British Tommies brought with them in a pipeline, up across the desert from Kantara on the Suez Canal, the sweet waters of the Nile, and they ran in the streets of Jerusalem.

Those waters of the Nile, for thousands of years, have carried fertility to a little band of greenery along the Desert River, spreading out in the great triangle of the delta, to water a land and make its people great because of their independence of weather and seasons. The granaries were sure. The river always came in flood. Great Egypt was in this respect different from the rest of the Sahara. But something else came with the life-giving water and sucked away the greatness of the people. Two lowly parasitic worms destroyed the grandeur of ancient Egypt and have held it in subjection even to this day. The hookworm is one of these, and the other is a schistosome worm, named after Dr. Bilharz, who discovered it in

1851. Modern scientific medicine has found the specific for each of these parasites. The hookworm has yielded to the strategic campaign of the American Rockefeller Foundation. Within the past few years Bilharzia has been cured by injection into the veins of solutions of tartar emetic. The Egyptian national board of health maintains fifty-two treatment stations for these two worm infections, the system centering in the laboratories and municipal hospital of Cairo. This century-old hospital, the Kasr el Aini, is being rebuilt on an island in the Nile. Thus modern medicine is restoring to Egypt what two minute worms took away, and the future only can see the result.

It is impossible to finish even these sketchy remarks on medical by-paths in the Orient without reverting to the two propositions with which we began. Religion and race are one. The rising tide of nationalism is irrepressible and must receive due reckoning. In our nearer Pacific Ocean, China stands out as the strong nation of the future. Geographically the Philippines belong to China. The eleven million Chinese outside China control a surprising share of the business of the Orient from Japan through Calcutta. Chinese by demonstration are capable of penetrating, controlling and governing the Philippines. Some day they may do so.

Three points at once become important. (1) For the good of the Philippines and the peace of the Orient, which is the peace of the world, the United States should govern the Philippines permanently on a colonial, dominion or territorial basis as may be determined. Withdrawal of the United States means leaving unprotected this enormous archipelago, bound by many ties to China, coveted by Japan, yet faced by the military power of France four hundred miles distant, and lying between the

CALIUB, LOWER EGYPT
GROUP OF PATIENTS AWAITING TREATMENT.

powerful jaws of the British lion in Hongkong and Singapore. (2) The United States must, of necessity, willing or not, face in the future a unified and powerful China. Discriminatory exclusion in the Philippines can not be enforced to-day and will not be tolerated either in the Philippines or the United States in another generation. Good judgment, justice and even self-interest unite with plain necessity in dictating that the United States guarantee fair play to China with reference to other great powers and that the United States cultivate the friendship of China in the strong relations of mutual acquaintance, assistance, forbearance and understanding. (3) One of the most powerful means of cementing international friendship and understanding is found in scientific institutions of broad and international scope and usefulness. Community of education and scientific study lead to friendly commercial and social relations. Such is the function of the Pacific Institute of Tropical Medicine being established in the University of California in San Francisco. The eyes of America are still turned westward. Trade must, more than ever, be built on acquaintance and personal friendship. The markets of the Orient are tremendous and competition for them is keen. Surely here we have a sound and logical common meeting-ground. Surely international good-will around the Pacific basin can be fostered in no more practical way.

COSMIC CLOUDS

By Dr. HARLAN T. STETSON
PERKINS OBSERVATORY, OHIO WESLEYAN UNIVERSITY

On the following page is a photograph of one of the conspicuously dark regions in the Milky Way. When Sir William Herschel first picked up one such region with his telescope and was aware of the sparsity of stars within it, he is said to have exclaimed, "Mein Gott, da ist ein Loch im Himmel!" (My God, there is a hole in the sky). In these apparently empty spaces Herschel believed he was looking out through our universe into the vacant recesses of space, far, far beyond the stars.

When Barnard, at the Yerkes Observatory a little more than a decade ago, was making his photographs of the Milky Way, he discovered a great many such dark regions. The more he studied his photographs the more firmly he became convinced that these dark regions in many cases were to be interpreted not as vacant spots devoid of stars but rather as dark patches of obscuring matter cutting off completely the light of the luminous stars beyond. It was the old problem of relativity again. This time it was not a question of relativity of motion, but a question of the relativity of background. Considerable skepticism prevailed at the promulgation of this heretical view-point. However, Barnard persisted in maintaining his interpretation and carried on with his photographic program. His accumulating photographic plates probably did more than anything he wrote about them to build up confidence in his newly propounded theory.

To-day the existence of large obscuring masses in the Milky Way and the existence of dark matter bordering many diffuse luminous nebulae is scarcely doubted. Other galaxies, such as the great nebula in Andromeda, reveal vast stretches of dark matter entangled in their spiral whirls, engulfing stars and obstructing them. Is it possible that in our own stellar universe our sun may now be in the midst of some such cloud, or can we be assured that while many other suns may be embedded in such murkiness our own is quite immune and we look skyward from our earth with the confidence that we see the stars through uncluttered space? This is a most vital question, for many of our estimates of distance to the remoter objects of our universe depend upon the assurance that light from those distant regions does not suffer diminution through traversing such enormous distances.

Many experiments have been made bearing on the problem. If the hypothetical ether which bears the light waves were a material homogeneous substance like water or air, then it should absorb some of the light traversing it. In consequence, like water or air, it should slightly disperse the light in accordance with its wave length. Blue light, therefore, should travel somewhat faster than red or yellow as it comes to us from a distant star. Fortunately this is easily tested by photographing the variations in the brightness of well-known variable stars in blue and yellow light simultaneously. Results show that there is no perceptible difference in the times of arrival of the blue and yellow light, even over extraordinary distances. Thus we may safely dismiss the question of absorption of light by the ether as more imaginary than real, a phrase probably quite as applicable to the ether itself.

DARK AND BRIGHT NEBULOUS MATTER IN THE VICINITY OF RHO OPHIUCHI

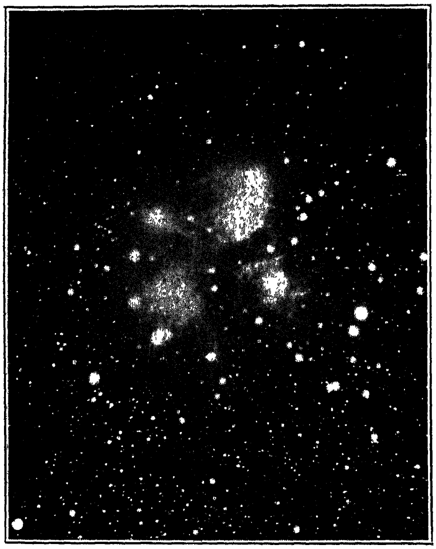
THE BLACK HOLE IN SAGITTARIUS

The question of the dimming of the distant stars by particles of dark obscuring matter is an entirely different affair. The obscuring power of a given amount (mass) of material varies greatly with the size of the particles of which it is composed. The smaller the particles, down to a certain limit, the greater will be the obscuring power, the maximum occurring when the finely divided particles are about a hundred thousandth of an inch in diameter or of the order of the wave-length of visible light. Thereafter as the particles become smaller they rapidly lose their power of stopping light. An astonishingly small amount of finely divided dust, such as smoke, for example, can produce a vast amount of dimming. Russell points out that a layer of dust containing only a tenth of a milligram for each square centimeter would be completely opaque no matter what its thickness, and on this basis the whole vast obscuring cloud in the constellation of Ophiuchus could be produced by a quantity of matter equal to hardly more than the amount of matter contained in a dozen of our suns. Of course if the solar system were now in any such cloud we should see no stars at all. The fact that our vision of the universe is as good as it is indicates that the sun's immediate neighborhood is reasonably transparent. On the other hand, there is evidence that space about us is not empty. The number of meteors falling to the earth is an indication of some of the larger lumps of cosmic material which abound in space and have presumably been captured by the solar system. It seems likely that a vast amount of such material from huge masses weighing tons down to the finest dust particles and gas molecules must be roaming at large in space until encountered and brought into local control by some passing star or planetary system. The existence of such cosmic clouds in the neighborhood of other stars gives rise to a certain amount of visible nebulosity where the light by which we photograph it appears to be reflected or excited from the nearby stars. A notable example of such a situation is to be found in the Pleiades.

Solar Corona

If the solar system were in the edge of such a cloud, however tenuous, we

NGC 4594 NEBULA SHOWING DARK ABSORBING MATTER



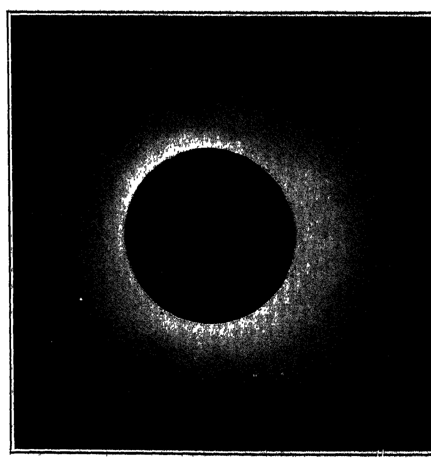
NEBULOSITY ABOUT THE PLEIADES
PROBABLY ILLUMINATED BY EXCITED RADIATION FROM THE NEIGHBORING STARS.

should expect to see some of it illuminated in the immediate vicinity of the sun whenever the direct sunlight was obscured, as in the case of a solar eclipse. It seems reasonable to suppose that we may account for a large part of the coronal illumination in this way, especially as regards the outer corona. In place of the structural details of the corona being produced by the particular way in which matter is thrown out from the sun, we should have in this hypothesis the material particles already existing about the sun, and their visibility brought about by the streaming of electrons along paths more or less definitely defined by the sun's electric and magnetic fields. The tendency of the streamers when present to group themselves somewhat symmetrically about the magnetic pole of the sun is consistent with such an interpretation. The form of the corona would not only be quite dependent upon the degree of solar activity, which varies with the sun-spot cycle, but at the same time would be influenced by the general density and distribution of the surrounding particles.

Zodiacal Light

Shortly after sunset and as soon as twilight has vanished there is visible in the tropics a conspicuous glow of diffused light extending upward from the sunset point sometimes all the way to the zenith. At its greatest breadth it subtends an angle of thirty to forty degrees. It is the zodiacal light. It may be seen in northern latitudes in the spring of the year after sunset or in the autumn before sunrise, although in neither case so conspicuously as in the tropics where its axis is more favorably situated with respect to the horizon. The usual explanation which has been offered for the phenomenon is that it is the reflection of sunlight from small meteoric particles circulating about the sun. It is appropriate to note that this phenomenon adds considerable support to the hypothesis of a circumsolar cloud.

Our observations of the zodiacal light made in the Indian Ocean on return from the Malaya eclipse of May 9,



THE SOLAR CORONA OF THE ECLIPSE OF 1926

(Swarthmore Expedition)

THE ILLUMINATION SUGGESTS EXCITATION OF A CIRCUMSOLAR COSMIC CLOUD BY EMITTED SOLAR RADIATION.

1929, revealed unmistakable fluctuations in its brightness over a period of two or three minutes. The literature of the subject reveals that similar fluctuations have been observed from time to time by other observers, notably by Chaplain George Jones, U. S. N., in 1854. The rapidity of the fluctuations suggests that we may be dealing with a neighboring material in cosmic cloud, excited by solar activity. Perhaps it is not without significance that the fluctuations observed in 1929 were concomitant with solar activity, as indeed is the general appearance of the corona itself. It might be added that on the day in question, May 31, 1929, when the fluctuations in brightness were most conspicuous, a naked-eye sun-spot was nearly centered on the solar disk.

A somewhat associated phenomenon is that of the *Gegenschein* or counterglow. This is a faint patch of light rather definitely circular in shape which may be seen under extremely favorable conditions at that point in the sky directly opposite the sun. The light is but a little more intense than that of the general sky illumination. It has been suggested that this, too, is the reflection of sunlight from small meteoric bodies at a considerable distance from the earth. In the theory of celestial mechanics there are dynamical grounds for suggesting this point as a rendezvous of meteoric material circulating about in the solar system. On the hypothesis of a spatial dust cloud it might be possible to account for such a patch of illumination as due to sunlight refracted into the earth's shadow by the shell of its atmosphere. The refraction of sunlight passing tangentially through the earth's atmosphere amounts to half a degree and would produce a luminous cone coming to a focus in space at a point 450,000 miles back of the earth. For a considerable distance inside this point a cloud of particles might be sufficiently illuminated to produce the observed effect.

Comets

Possibly a further argument for the existence of a circumsolar cloud is to be found in the behavior of comets' tails. It is common knowledge in astronomy that the tails of comets inevitably stream in a direction away from the sun. It has generally been supposed that all the material in the tail of a comet has been ejected from the head and borne away from the sun by the repulsive force of solar radiation. There is some difficulty, however, on such a hypothesis, in accounting for the radical shift in the direction of a comet's tail as it rounds the sun. In some instances where the comet passes the sun at a close range the tail must whiff about through one hundred and eighty degrees in the space of a few hours. For material particles to be emitted from the head at a rate to resupply a tail a hundred million miles long, under such circumstances, demands almost unthinkable velocities. On the other hand, if we suppose the general illumination of the tail to be produced from the excitation of a cosmic cloud of dust and gas by streaming electrons from the comet's head, the change in the direction of the tail illumination will take place with the speed of electronic emission, even comparable with that of light. Moreover, sudden changes in the illumination and form of the tail are often observed, notably in the case of Morehouse's comet in 1908, which, very difficult to explain on the basis of the light-pressure theory, appear plausible on the new hypothesis. The fact that faint stars have appeared undimmed by the tails of comets appears to be no surprise on the supposition that the bulk of the material composing the tail was already there in space. The stars would shine through it equally well whether it was illuminated or not. In any event the density of the material must on the

average be very low. Calculations in the case of Halley's comet have shown that *on the average* the amount of stuff in two thousand cubic miles of the tail was not greater than that in a single cubic inch of ordinary air. However, this does not preclude the existence of lumps of matter of considerable density widely scattered through space. Barnard, in studying his many photographs of comets, often spoke of sudden changes in the appearance of the tails suggesting encounters with a "resisting medium." Such abrupt changes might well occur on those relatively rare occasions when a comet would pass into some local aggregation of cosmic cloud in the vicinity of the sun.

Dimming of Stars

If the solar system now were in the midst of a cosmic cloud of indefinite extent, then of course the stars would appear increasingly fainter than they should with increasing distance from the earth. Such does not appear to be the case. If, on the other hand, we suppose our cloud to be more or less a local affair extending perhaps not more than a hundred light years or so, only those stars within that distance would be so affected. The number of such stars is comparatively small. Beyond that distance all stars would be dimmed the same amount as far as any obscuring power of this local cloud is concerned. It has been argued that, since blue light is scattered by small particles much more than red light, the more distant stars should appear redder than the nearer ones, whereas in general we find that the more distant stars are the bluer ones. It is easy to see, however, that the effect would not be a progressive one unless the hypothetical cloud extended to the remotest stars. Furthermore, to produce the selective scattering it would have to be composed of the finest dust powder imaginable. A gathering sea fog dims and ultimately obscures the distant lighthouse without in any way altering its color. The small particles in this case are too big to introduce a selective absorption or scattering. If there were a sufficient number of stars within the limits tentatively set to our local cloud, and the cloud contained a large enough percentage of the finest pulverized matter, then we might expect to find some tendency for the stars near the boundary of this cloud to appear redder than those closest at hand. Apropos of this delicate test, Professor King, of the Harvard Observatory, has recently announced that he does find some unmistakable evidence that the nearest stars of a given class are somewhat bluer than similar stars seen at a greater distance. He believes that his results support this circumsolar cloud hypothesis.

While many of the bluest stars are at great distances from the earth, there is nothing against the supposition that these terrifically hot stars would appear actually bluer than they do, were it not for the presence of some amount of selective scattering which reduces the percentage of the light of shorter wavelengths reaching the earth. I would suggest as a further bit of evidence in this direction the well-recognized discrepancy between the theoretical temperatures of the stars and temperatures derived from observational data. For many years the temperatures of stars have been determined observationally by measuring the distribution of the light intensity throughout their spectra. According to well-known laws of radiation expressed by Wien and by Planck the wave-length of the part of the spectrum showing the maximum intensity of illumination is an index of the temperature of a luminous body. The temperatures of the stars derived in this way have generally been found to be lower than those deduced from modern atomic considerations in accordance with

the ionization theory of the Indian physicist, Saha. This discrepancy can perhaps be reconciled if we allow for a small deficiency in the blue light of the spectrum of the hottest and more distant stars caused by the selective scattering from a cosmic dust cloud.

Ionized Calcium

An irrefutable argument for the mere existence of interstellar matter is to be found in the almost universal presence of the dark absorption lines of ionized calcium in the spectra of stars. These lines do not shift about with other lines in a star's spectrum in accordance with Doppler's principle, and give silent testimony to the existence of vast clouds of calcium lying between us and the distant stars. Eddington in his "Stars and Atoms" estimates that in all space within our galactic system there must be on the average one atom of calcium for every cubic inch. While the existence of calcium atoms in interstellar space would readily account for the selective absorption of light as represented by the dark calcium lines, these atoms would not of themselves cause any general dimming in the light of the stars shining through. A general dimming would have to be caused by lumps of matter larger than single atoms. If, however, we have such unmistakable evidence for some of the building blocks of matter permeating all space, does it seem unreasonable to suppose that there should exist aggregations of these building blocks in bundles of sufficient size to cause appreciable obstruction to the light from distant stars?

Again, apropos of this thesis we may do well to note that the stars in general appear to be only about one tenth as luminous as Eddington says they should appear on theoretical grounds. This is the equivalent of saying that, as the astronomer measures brightness, the majority of the stars appear about two and a half magnitudes fainter than they should. Calculation shows that, with no allowance for scattering, an obscuration of light of this amount could be produced by opaque particles a millimeter in diameter distributed more or less uniformly throughout a cloud a hundred light years in diameter with but one such particle to every one hundred and forty cubic miles. Even so the density of the hypothetical cloud would be less than one million million millionth (1×10^{-19}) that of air, and the total mass would be about that of 200,000 stars the size of the sun. Allowing for scattering, the amount of matter needed to produce the effect would be much less.

Possible Effects on Solar Radiation

Whatever further researches may reveal in regard to this problem, it seems most certain that, in the sun's migrations through the universe, the solar system must often encounter some vast clouds of the Milky Way. What the effect on the earth may be in such circumstances it is interesting to reflect. If the cloud should be of considerable density it is more than likely that the temperature of the earth would be materially lowered. Observations of solar radiation have shown that in years of great volcanic eruptions the amount of heat received by the earth from the sun has been considerably less than the normal quantity. Notable instances of this occurred in the cases of Krakatoa, Pelée and Katmai.

On each of these occasions the terrific eruptive force of the volcano hurled tons of pulverized dust into the upper atmosphere which did not return to earth for many months. Carried by upper air currents it was spread in a thin layer around the entire globe. The dust particles acted much as a screen to the radiation of the sun and were undoubtedly responsible for the decreased

solar radiation reaching the earth during those years. If such can be the effect of a relatively thin shell of volcanic dust it is more than likely that the passage of the solar system through a cosmic dust cloud would result in lowering the temperature of the earth by several degrees. If such lowered temperature were to persist for any considerable length of time winter snows would cease to melt and an ice sheet of vast extent would gradually form in the otherwise temperate zones. This appears to be one of the most plausible explanations of the well-known glacial periods of geologic history.

To add zest to this contention we have only to note that the constellation of Orion which is completely enshrouded in nebulosity lies not far from the wake of the sun's motion through space. One of the darkest patches of cosmic fog ever photographed lies just south of the well-known nebula in the sword of Orion. Recent investigations at the Mount Wilson Observatory indicate that the luminous part of the great nebula itself is rendered visible by the action of the Orion stars upon the neighboring regions of a vast dark cloud. The part of the great nebula so rendered luminous must be as far away as the adjacent stars. This is about a hundred and fifty light years. The distance may be overestimated, however, as in obtaining such results no allowance has been made for a possible dimming in the brightness of the stars due to any absorption or obstruction of light by any portion of the nebula itself. Apart from this question, it appears that since the whole region of visible nebulosity covers an area of some twelve hundred square degrees, the distance from the earth to the borders of this great cloud may be but a small fraction of the estimated distance.

It seems more than plausible that at the times of the great ice ages several thousands of years ago the sun may have been in the region of space where existed a cosmic cloud of considerable dimensions. The wide variations in temperature which the earth has undergone for considerable periods in geologic time seem to be more satisfactorily accounted for on such a basis than on the supposition that the sun itself experienced any considerable variation in its output in the last hundred million years. Geologists tell us that the earth at present appears be emerging from the last glacial epoch and that balmier climates are in store. We might interpret this astronomically by supposing that we are emerging from the last encounter with any cosmic cloud of appreciable density and are perhaps just clearing the outer reaches of an attenuated region. What lies ahead and how soon the sun may again engulf us in an interspatial fog only imagination can venture to speculate. One ventures to suggest that investigations of the earth's cosmical environment will play an important rôle in the next decade of astronomy. To what degree interspatial matter may yet modify our view of the universe only the most painstaking research can safely divulge.

CHINESE ALCHEMY

By Dr. TENNEY L. DAVIS and LU-CH'IANG WU

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ALCHEMY appears to have arisen spontaneously in China, possibly as an outgrowth from the magical and fantastic side of the Taoist religion. As early as the second century before Christ, perhaps earlier, Chinese alchemists were engaged in the study of mineral substances, particularly cinnabar, in the hope of finding the elixir of immortality and the philosopher's stone. They sought to convert base metals into gold, not because of the intrinsic value of that metal, but because artificial gold, if used as the material for eating vessels, was supposed to produce longevity. The priority of Chinese alchemy now appears to be well established.[1] The similarity of its aims and its materials with those of the later Greek, Arab and medieval Latin alchemy has led scholars to infer that they all derive from a common source,[2] or even to conclude that European alchemy probably had its origin in that of the Chinese.[3] At any rate, definite trade routes between China and the Roman Empire were established, mainly by way of Alexandria, as early as the first or second century of the Christian era, at a time when alchemy was certainly well developed in China but at least a century before the active rise of alchemy in Alexandria.

TAOIST ORIGINS OF CHINESE ALCHEMY

Whether Chinese alchemy arose out of the magical and fantastic side of the Taoist religion, as Johnson and others believe, it nevertheless seems to be the case that Taoism and alchemy attracted the same scholars. The same individuals practiced both professions and wrote upon both subjects. The Taoist Canon contains many treatises on alchemy and is a veritable treasure-house ready for future students of Chinese alchemy. Wieger's bibliography[4] of Taoism lists 1,464 titles of which 132 indicate that the treatises relate to alchemy. Of these 132, twenty-one titles suggest that the treatises deal with the spiritual, moral, metaphysical, physiological or mystical side of alchemy. Alchemy of spirit and alchemy of matter had the same confusion, or perhaps liaison, among the Chinese that they later had among the Europeans.

WU-HSING AND YIN-YANG[5]

Long before the founding of Taoism by Lao Tzŭ (1088)[6] (604–500 B. C.), the Chinese had very definite notions relative to the constitution of natural things. Wu-hsing (the quintet), water, fire, wood, gold (or metal) and earth, were regarded as the material principles of natural objects. The term, Wu-hsing, at first had no magical significance. One of the earliest cases of its use is in the Hung-fan (Great Plan) chapter of the "Book of Historical Documents": "In

[1] The Reverend Joseph Edkins, *Trans. China Branch Roy. Asiatic Soc.*, Hong Kong, 1855, part 5, pp. 83–99. J. R. Partington, *Nature*, 119: 11, 1927; 120: 158, 1927. B. F. Read, *Nature*, 120: 877–878, 1927.

[2] H. E. Stapleton, R. F. Azo and H. M. Husain, *Mem. Asiatic Soc. of Bengal*, 8: 405–406 (footnote), 1927.

[3] Obed S. Johnson, "A Study of Chinese Alchemy," The Commercial Press, Ltd., Shanghai, 1928.

[4] Dr. Leon Wieger, S. J., "Taoisme," 2 vols., Ho-kien-fou, 1911, 1913.

[5] Ch'i-Ch'ao Liang, "On the Origin and Evolution of the Doctrines of Yin Yang and Wu-hsing" (in Chinese), *Eastern Miscellany*, Shanghai, Vol. 20, No. 10, pp. 70–79, 1923. Translation by Lu-Ch'iang Wu.

[6] In order to avoid confusions of identity, the names of Chinese individuals are followed by the numbers which correspond to them in Giles' "Chinese Biographical Dictionary," London, 1898.

the olden days, so I heard, in the time of Kun (1018), a deluge overran the Kingdom putting Wu-hsing at nought." Liang says that this ought to be interpreted as meaning that on account of the deluge all the things which can be classified by Wu-hsing (or the five categories) became unavailable for man's use. The Hung-fan chapter says further:

> Wu-hsing [the quintet]: first, water; second, fire; third, wood; fourth, gold (or metal), and fifth, earth. Water is that which soaks and descends; fire that which blazes and ascends; wood that which is straight and crooked; gold (or metal) that which obeys and changes, and earth that which is of use for seed-sowing and harvest. That which soaks and descends becomes salt; that which blazes and ascends becomes bitter; that which is crooked and straight becomes sour; that which obeys and changes becomes acrid, and from seed-sowing and harvest comes sweetness.

The Wu-hsing are here plainly the constituent elements of material things. Tso Ch'iu Ming (2024), disciple of Confucius (1043), said that "nature provides the five materials and the people use them all."

Although the term, Wu-hsing, at first meant only the five elements, it later took on an occult and magical connotation and was used in connection with the five ways of righteous conduct, the five social relationships, the five virtues, the five tastes, the five colors, the five tones, etc. The earliest and most fantastic and systematic treatment of Wu-hsing occurs, according to Liang, in Lü Shih Ch'un Ch'iu Shih Er Lan by Lü Pu-wei (1455) (died 235 B. C.). It was later adopted in Hsiao Tai Li Chi by Tai Shêng (1853) (second to first century B. C.) and still later by Huai Nan Tzŭ (1269) (died 122 B. C.). Liang says that:

> The seasons of the year were thus divided among the Wu-hsing: spring, *wood;* summer, *fire;* autumn, *gold;* winter, *water*, and, in order to complete the story, they even went so far as to assign the interim between summer and autumn to *earth.* In a similar manner the magic quintet was correlated with the five locations: east, west, north, south and center; with the five colors: blue, red, yellow, white and black; with the five tones: Kung, Shang, Ko, Cheng and Yü; with the five tastes: sour, bitter, salty, astringent and sweet; with the five animated species: furred, shelled, scaly, feathered and nude; with the five worships: of wells, of furnaces, of doors, of eaves and of sacred roadways; with the five grains; with the five domesticated animals: horse, ox, sheep, dog and hog; the five internal organs of the human body: heart, liver, lungs, pancreas and kidneys; with the five rulers of ancient China: T'ai Hao, Yen Ti, Huang Ti, Shao Hao and Chuan Hsu, and with the five gods: Chü Wang, Chu Yung, Ho T'u, You Show and Hsuen Ming. . . . Thus the thousand and one entities of the universe have been ruthlessly forced into five categories corresponding to Wu-hsing. This fantastic mood has been dominating the mind of the nation for at least two thousand years and more, and has often manifested itself in deeds. It holds sway over the medical profession which has our lives in its hands. It is incarnated in our national flag.

While the notion of Wu-hsing as a genuine scientific concept (in its original meaning of the five elements) remounts to the twelfth century B. C., the scientific notion of Yin-Yang, or the two contrary principles, appears to have become definite at a later time, probably after Confucius (1043) (551–479 B. C.). Wu-hsing and Yin-Yang occur frequently in the writings of the Chinese alchemists, and they have real scientific meaning and usefulness. But they are also often aligned in magical and fantastic relationships in a manner similar to that in which the Alexandrian and Latin alchemists of Europe handled the notions of the contraries (sulphur and mercury, for example), and of the numbers three, seven, etc.

Yin, according to Liang, originally had the meaning of covering the sun with clouds. It came to mean shaded, dim, beclouded and, since Chinese cities were generally laid out with the principal entrance on the southern side, it meant the northern or shaded side of the city, also the south side of a river, the

interior, the reverse and the north side of a mountain. The word Yang originally signified "the bright aspect of banners fluttering at sunrise," but it soon acquired the meaning of the brilliancy of the sun, hence sunlight, warmth, the face-side, the exterior, the south side of a city or of a mountain. The couplet Yin-Yang was used to signify opposites, such as north and south, reverse and obverse, and this was without magical connotation and without the belief that the opposites were scientific categories by which the endless diversity of nature might be understood and classified. The words Yin and Yang, moreover, were used separately more often than they were used together.

Liang states that the I Li, or "Book of Rites and Ceremonies," does not contain either of the words. In the Shih Ching, or "Book of Poetry," the word Yin is used eight times; the word Yang, fourteen times, and the phrase Yin-Yang, only once and then in its original meaning of light and shade. The I Ching, or "Book of Change," uses Yin only once and Yang not at all. The commentaries on the "Book of Change" which are ascribed to Confucius are devoted to an exposition of that philosopher's dualism. He conceived the universe as embracing two kinds of forces which by interaction gave rise to the diverse facts of nature. The forces were not easy to describe; and he referred to them as Kang Jou, hard and soft; Tung Tsing, motion and rest; Hsiao Hsi, subtraction and addition; Ch'ü Shen, bending and unbending; Wang Lai, going and coming; Tsin T'ui, going forward and backward; Hsi Pi, folding and unfolding; as well as Yin Yang; but the latter is much less frequently mentioned than some of the other pairs. In short, Yin and Yang, as used by Confucius, had no magical connotation but did have, along with other pairs of terms, a certain philosophical and scientific value for the discussion of natural phenomena.

The notion of Yin-Yang gradually became extended until in the writings of the Taoists and alchemists it appears as a fundamental cosmological concept having innumerable fantastic associations. It was supposed that the primal matter, T'ai Chi, in its gyrations gradually separated into two parts. The heavy and gross part, Yin, settled and formed the earth, while the fine and light part, Yang, remained suspended and formed the heavens. Together they were the Liang I, or the two regulating powers, and constituted the soul of the universe.

> Yin was regarded as the female element, typifying in general the more undesirable phenomena of nature, such as cold, darkness, weakness and death. Yang was regarded as the male element, which was, in turn, representative of the qualities in direct opposition to those of the Yin. From the interaction of these two cosmic forces, the universe was created and, in its various phases, directed and controlled. As time went on, this principle of dualism came to be a most potent factor in Chinese thought, for it permeated both the material and the moral world. At a later date, it was adopted as one of the cardinal beliefs of Confucianism, and as such it has exerted a momentous influence on the Chinese mind for more than twenty centuries.[7]

Prior to the time of the Feudal Kingdoms (722–481 B. C.) the phrases Yin-Yang and Wu-hsing were of rare occurrence and possessed only their ordinary meanings. They do not occur together in the writings of Confucius, Lao Tzŭ (1088), Mo Tzŭ (1537), Mencius (1522), Hsün Tzŭ (807) or Han-fei Tzŭ (614). Liang believes that the doctrines of Yin-Yang and Wu-hsing were first elaborated and spread by the divinationists, astrologers and magicians of Yen and Ch'i (the present provinces of Shantung, Honan and Chihli), in particular by Tsou Yen (2030) (fourth to third century B. C.), Liu Hsiang (1300) (80–09 B. C.) and Tung Chung-shu

[7] Johnson, *op. cit.*, pp. 14, 15.

(2092) (second century B. C.). Although the writings of Tsou Yen are no longer extant, their purport can be gathered from the references to them in the historical writings of Ssu-ma Ch'ien (1750) (born about 145 B. C., died 86 or 74 B. C.). Liang concludes that Tsou Yen "was the fanatic who started the uncomely and uncouth doctrines." Ssu-ma T'an (1762) (died 110 B. C.), the father of Ssu-ma Ch'ien, placed Yin-Yang-ism on a par with Confucianism, Taoism, Mo-ism, Nominalism and Legalism, and wrote an essay on the "Essence of the Six Schools." We infer that by his time the doctrines had been pretty fully elaborated into the form in which they pervade the writings of the alchemists.

Alchemists and Alchemical Writings

Ch'in Shih Huang Ti.—Ssu-ma Ch'ien succeeded his father as grand astrologer or grand annalist to the Chinese court and completed the Shih-chi, or "Historical Memoirs," which his father had commenced. The Shih-chi deals with the history of China from the earliest times to 122 B. C. It tells of the islands of the immortals and reports the earliest organized attempt in Chinese history to secure the elixir of life. It is reported that in the midst of the Eastern Sea there are three supernatural islands. Their names are P'eng Lai, Fang Chang and Ying Chou. It is there that the immortals may be found, and the drug which prevents death. The Emperor Ch'in Shih Huang Ti (1712) (259–210 B. C.), the same who established a new dynasty, built the Great Wall and introduced the hair-pencil or brush for writing on silk instead of on bamboo tablets, became interested by the report of these islands and especially by what he heard concerning the elixir of immortality. He was influenced by the magicians Lu Shêng (1428) and Hsü Shih (788) to organize an elaborate naval expedition for the purpose of searching for them.

> He gave to Hsü Shih seeds of the five grains and dispatched him upon his voyage with three thousand young men and women, and laborers for all kinds of work. Hsü Shih sailed away, and discovered a locality noted for its peace and fertility. There he tarried, was made king, and did not return.

The Emperor, however, continued to hope. He made several pilgrimages to the eastern coast of China. He consulted with magicians, but feared to trust himself to the sea.

> It was his custom to promenade up and down the seashore, in the hope that he might in some manner obtain the wonder-working drug of the three sacred islands in the midst of the sea—but he never obtained it. He returned to Sha Ch'iu—and there he died.[8]

Li Shao Chün and Han Wu Ti.—The historian Ssu-ma Ch'ien also tells of an alchemist, Li Shao Chün (1189), who flourished at the court of the Han Emperor, Wu Ti (1276) (156–87 B. C.).

> He constantly affirmed that he was seventy years of age, that he was able to rule over spiritual matters and that he could escape old age. . . . He traveled about in order that reports of his prowess might reach the ears of nobility. . . . He excelled in showing himself shrewd, and in saying things at the same time astounding and accurate.

Through his influence the Emperor became interested in alchemy. Li Shao Chün said, "I know how cinnabar transforms its nature and passes into yellow gold. I can rein the flying dragon and visit the extremities of the earth. I can bestride the hoary crane and soar above the nine degrees of Heaven." He gave particular instruction to the Emperor. "If you will make the sacrifice of the furnace, you will be able to transmute cinnabar into gold. When the gold shall have been produced, you may make of it utensils for eating and drinking. Through using them your life will be prolonged, so that you may see the blessed immortals of the islands of

[8] Johnson, *op. cit.*, pp. 66–68.

P'eng Lai, which lie in the midst of the ocean. When you shall have seen them, and shall have made proper sacrifices to high heaven and broad earth—then you will never die." It is further recorded that

> it was after this discourse that the Son of Heaven [the Emperor] for the first time performed in person the sacrifices of the furnace. . . . He occupied himself in experimenting with powdered cinnabar, and all sorts of drugs, in order that he might obtain gold.[9]

Liu An or Huai Nan Tzŭ.—Liu An (1269) (died 122 B. C.) was a grandson of the first Han Emperor, prince of Huai Nan, and an ardent Taoist and alchemist, a searcher after the elixir of immortality and the secret of the transmutation of the metals. He praised the art of proper breathing, saying that "he who consumes the atmosphere becomes spiritual and attains extreme old age." He also spoke of the regions of the extreme West "where there are rock cities and gold dwellings, and where human beings and wild animals 'drink the atmosphere' and do not die." He taught that "gold grows in the earth by a slow process, and is evolved from the immaterial principle underlying the universe, passing from one form to another up to silver and then from silver to gold." Under the pseudonym of Huai Nan Tzŭ he wrote a treatise which contains considerable alchemy, and his Hung lieh chieh ("Story of the Great Light") deals with cosmogony and embodies alchemical doctrines. Both works are part of the Taoist canon.[10]

Wei Po-Yang.—The Taoist philosopher Wei Po-Yang (2287) flourished about A. D. 142 and wrote the Ts'an T'ung Ch'i, a "Treatise on Alchemy," which is based upon the "Book of Change" and is regarded as the earliest purely alchemical treatise in the Chinese language.[11] It is included in the Taoist canon and in the Ssu-ku-ch'uan-shu (Imperial Encyclopedia). A recently printed text consists of eighty-two chapters and an additional section entitled "The Song of the Ting (Furnace)."

The Ts'an T'ung Ch'i makes frequent reference to the pill of immortality and contains abundant evidence of an earlier alchemical tradition. It mentions the obscurity of earlier writers and states that its author is making an effort to be clear in spite of his feeling of inferiority and inadequacy for the task. It describes the processes about as lucidly as the writings of the medieval alchemists. It gives symbolic and imaginative names to many of the substances which are used, and insists upon the necessity for careful and accurate compounding and for a cautious interpretation of the text which, the author says, he has intentionally obscured in places. In many respects it bears a strong resemblance to the later alchemical writings of the Europeans.

> In order that the [ancient] writings on fire shall not have been in vain, I explain here in simple language.
>
> Like the moon lying on its back is the shape of the furnace and the pot. In it is heated Pai Hu [White Tiger]. Kung Jih [Mercury Sun] is the flowing pearl and with it is Ch'ing Lung [Blue Dragon]. The East and the West merge together and so the Yün and P'eh[12] restrain one another.
>
> When gold is placed in a hot fire, it is not deprived of the brilliancy of its color. Since the days of the unfolding of the Universe, the sun and the moon have not diminished in brightness nor has gold lost any weight. The shapes of the sun and moon have always been

[9] Johnson, *op. cit.*, p. 70, footnote; pp. 76–77.

[10] Johnson, *op. cit.*, pp. 47, 75, footnote. Sarton, "Introduction to the History of Science," Vol. I, p. 193, Baltimore, 1927.

[11] An English translation of this work is at present in course of preparation by Lu-Ch'iang Wu. We quote portions of it.

[12] Yün denotes the lighter element of man's nature and P'eh the heavier and more earthly. Upon death the former rises to the skies while the latter stays and is buried with the body.

the same. Gold is born under the influence of the moon. At daybreak, receiving magic force from the sun, it returns to its mother. Being enveloped by the sun at the wane of the moon, it hides within the walls and abandons itself to inanity. Thus does the gold regain its original nature. Only when intense brightness is obtained is the Ting [furnace] well heated.

Tzŭ Wu amounts to three and Wu Chi is called five. The three and the five having been harmonized, the eight stones are put into proper order. They desire one another's presence in their inhalation and exhalation, and they long to be man and wife. Yellow earth is the father of gold and flowing pearl is the mother of water. Earth is the Kwei [ghost] of water and it is not able to arise because of the overbearing of the earth. The Chu Ch'ueh [Red Bird or the seven fixed stars of the southern sky] is the spirit of fire and dispenses victory or defeat with justice. With the ascendance of water comes the vanquishing of fire. Dying together they return to Mother Earth. The three natures merge together and thus show their common origin.

Longevity counts very much in the great triumph. Huan Tan [Returned Medicine] is edible. The nature of gold is non-corruptible and it is therefore the most valuable of things. The Shu Shih feeding on it attain longevity. . . . The Chin Sa [gold dust], being in the internal organs, spreads foggily like wind-driven rain. Vaporizing and permeating, it reaches the four limbs. Thereupon the complexion becomes rejuvenated, hoary hair regains its blackness, and new teeth grow where fallen ones used to be. If an old man, he will once more become a youth; if an old woman, she will regain her maidenhood. Such transformations make one immune to worldly miseries, and one who is so transformed is called by the name of Tsun Jen.

Hu powder, on being placed in the fire, becomes discolored and changes back into lead. On treatment with hot liquids, ice and snow dissolve into T'ai Hsuen [*i.e.*, an exceedingly intangible principle]. Gold is chiefly made up of sand and derives other properties from mercury. The transformations concern only the essence of the materials. Causes and effects are traceable in the course of the changes. The way to make oneself a Fu Shih Hsien [a drug-using supernatural being] lies in the use of drugs of a nature similar to oneself. For rice seeds are used in the raising of rice, and chicken are hatched from hen's eggs. . . . Fish eyes can not replace pearls, and tall weeds can not be used for timber. Things of similar nature go together. Queer things can not be realized. This explains why the swallow does not give birth to peacocks, and the fox and rabbit do not mother horses. This also explains why flowing water does not heat up what is above it and why moving fire does not wet what is under it.

Many are the learned scholars, but they are too profound to be understood and are therefore lost to the world. They never meet with proper patronage. Their belongings are devoured by devastating fire. They follow the printed word and sometimes they follow their blind inclinations. The start they make is improper and subsequent regulation is wanting.[13] Chiang Shih Tan [a kind of stone], mother-of-pearl and alum are crushed together and cured. Sulphur is burned with Yü-Chang wood. Mud and mercury are treated in a mixture. This forms the pivot of the five stone coppers under the drum. Things of different nature and kind are unwilling to unite and live together.[14] Ten thousand defeats will come from a thousand attempts. Doubts will fill the heart in middle age. . . .

The Essay on Fire comprises six hundred chapters. Their subject-matters are not the same. They are so cautiously worded that they are not easily understood by people of the world. When things are traced back to their origin, it will be found that the bright and the

[13] Compare Albertus Magnus in the treatise "De Alchemia": "For I have seen certain men who made their sublimations with great diligence but were not able to proceed farther because they did not have the fundamentals. And I have seen others who had a good beginning but because of too much potation and other vanities were not able to accomplish the work." And, in the advice which he gives to the person desirous of undertaking the study of alchemy, "The fourth precept is that the worker in this art should be sedulous and frequent in his operations, and should not tire but should persevere to the end. Because, if he should begin and should not persevere, both time and substance would be lost." "Theatrum Chemicum," Vol. II, pp. 487, 491, Ursellis, 1602.

[14] The author of the "Speculum Alchemiae," which is ascribed to Roger Bacon, insists upon the fact that the philosopher's stone can transmute only a substance which has a nature allied to its own. "On this point I now reveal to you a great and hidden secret. One part ought to be mixed with a thousand parts of an allied substance, and the whole shut up tightly in a suitable vessel, etc. . . . always one part of this for another thousand of an allied substance." "Theatrum Chemicum," Vol. II, p. 442.

dark [the obvious and the obscure] are in close union. A profound thing like this is fit to be treated only by the wise. It is presumptuous therefore for me to write on it. But I can not hold my peace either; for it would be a great sin on my part not to transmit the Tao [Way] which would otherwise be lost to the world forever. I will not write on silk lest the divine secret be spread abroad. In hesitation I sigh. . . . Details of the processes shall not be entirely divulged. Only the more important principles shall be set forth.[15]

Gold should be used for the embankments, for then the water and the fire can have their proper play. The number of gold is fifteen; so is that of water. Take measurement when the process is about to begin. One half water is more than enough. The two things will be made into an essence—enter into one another, undergoing marvelous changes. The T'ai Yang Ch'i [the Most Positive Ether] which is underneath gives rise to distillation instantly. Liquefaction takes place first, followed by solidification. This is known as Huang Yü [Yellow Carriage]. . . . It is bodily transformed into a white dust resembling that deposited on a well-lighted window sill.

Treatment and mixing will bring about combination and rapid entrance to the scarlet portal. The escape must be firmly blocked. Below the flame plays noisily on the under side day and night. The flame at the start should be weak, and it should be made strong at the end. Close attention and careful watch should be given so as properly to regulate the temperature. Revolve about the twelve sections. At the end of that a closer watch should be accorded. As the breath expires life is ended. Death expels the spirit. The color changes to a purple.[16] Behold! the Huan Tan [Returned Medicine] is obtained. This is then made into pills with the help of wieldy knives and blades. . . .

Huan Tan [Returned Medicine] is obtained only when gold has returned to its original own. I do not dare say things without ground, nor imitate the sayings of the sages. The ancient "Treatise on Fire" takes note of the Dragon and the Tiger; Emperor Huang Ti (1712) praises the Flower of Gold; Huai Nan Tzŭ (1269) assays the Ch'iu Shih [Autumn Stone]; and Wang Yang (?) adds Huang Ya [Yellow Shoot] to this series of achievements. The sagacious follow the discipline strictly. The unworthy can not aspire to this. The way has been one since ancient times. One's projects are to be divulged only on personal interview. The student should be industrious and thoughtful. Important things have been set forth plainly. They are unmistakably clear.

The author speaks of the difficulty of the art and of the necessity for right judgement.

People like trivial acts. They do not understand the Tao [Way]. Abandoning the right road and following vicious by-paths in the hope of pursuing a short cut, they finally find themselves to be at the closed end of a blind alley. This is like the blind man who goes about without the help of a staff, or the deaf man who goes to listen to music. One might as well look for rabbits and birds under water, or try to get fish and dragons in a mountain. One might as well plant wheat to get barley, or use a pair of compasses to draw a square. Energy is thus wasted and the spirit torn away for long years without success. However, it is a simple matter to learn the method of using internal medicine. . . .

It is difficult to make representations of things which one does not understand. One may spend so much of what he has as to bring want and hunger home to his wife and children and yet he will not be able to arrive at the truth. Many have there been who have thus

[15] Compare Albertus Magnus in "De Alchemia" (*loc. cit.*, pp. 486–487): "I who am truly the least of the Philosophers intend to write about the true art for my associates and friends, clearly and infallibly, but however in such manner that seeing, they may not see, and hearing, they may not understand. Wherefore I beg and adjure you, by the Creator of the world, that you hide this book from all stupid persons. To you indeed I will reveal the secret, but from others I conceal the Secret of secrets because of the envy of this noble science. For the stupid despise it because they are not able to grasp it, and thence hold it hateful and believe it not to be possible, and so envy those who work at it and call them forgers. Therefore beware lest you reveal any of our secrets in this operation. Again I advise you that you be cautious, persevere in the operations, and avoid fastidiousness for you know that great utility follows after your work."

[16] The Alexandrian alchemists regarded purple as the noblest of the colors. In the process of the transmutation of a base metal into gold there were various changes of color, and the appearance of a purple marked the completion of the process. From the time of Zosimos, about 400 A. D., it was understood that the color sequence was black, white, yellow and violet. *Vide* Arthur John Hopkins, *Isis*, 7: 58, 1925; also "Studien zur Geschichte der Chemie. Festgabe für Edmund O. v. Lippmann," Berlin, 1927, pp. 9, ff.

devoted themselves to the cause. But very few of these have met with the good fortune of success. In that they searched far and wide for reputed medicines they fell into a path which is incompatible with the Tao. One should take note of hints and clues *just as he would when he meets strangers.* The thing to do is to compare things by classes and to trace their beginnings and ends.

The following passage shows the fantastic language which the alchemists used occasionally:

Tan Sha [Red Sand or cinnabar] is of wood and will combine with gold. Gold and Water live together: Wood and Fire keep one another company. The four are in a confused state. They are classified as Tiger or Dragon. The magical number of the Yang Dragon is odd and that of the Yin Tiger is even. The blue pancreas is the father and the white lungs is the mother. The black kidneys are the sons and the yellow spleen is the grandfather. The three things are of the same family and they all belong to the ordinal numbers of Wu and Tsih.

The necessity for accuracy:

When compounding is not properly made, law and order will be upset. Under such conditions, even with Huang Ti (1712) to operate the furnace, with the Supreme One to confer blessing on the operation, with the Eight Deities to help compounding, with Huai Nan (1269) to control the fire, with prayers offered on bended knees on a dignified altar in a magnificent temple decorated with jades, with sacrifices of Lin [a sacred animal] and of Feng [a sacred bird] made to the spirits by the purified and dieting seeker in the vain hope of success, even then failure will still be inevitable. For this is just as absurd as repairing a cooking vessel with glue, or trying to heal a boil with Nu [sal ammoniac], or trying to get rid of cold with ice, or attempting to get rid of warmth with a hot fluid, and reports of flying turtles and dancing snakes.

The reason for the treatise:

Oh, the sages of old. They held in their breasts the elements of profundity and truth. Having prepared and partaken of the medicines prepared in the nine Tings [Furnaces or Vases, usually with three legs], they were endowed with the power to disappear at will. They held the essence firmly and cultivated their spirit, and they thereby attained communion with the *three primes.* The essential fluids worked properly to give them strong bones and muscles. The various evils were banished forever and the good Ch'i came to stay forever. In the course of time they became deities. Their sympathy, for those of posterity who have a liking for the attainment of the Tao, caused them to explain the writings of old with words and illustrations. They expressed their ideas by the names of stones and in vague language. Those who understood their sayings held their peace. The secret was handed down in the family from generation to generation. The world at large was ignorant of it. In the attempt to learn it the politician cut short his career, the farmer neglected his farm, the merchant stopped trading and the ambitious scholar became poverty-stricken. These grieve me. Therefore I execute the present writing. Although concise and simple, yet it embraces the essential points. The proper quantities to be used are put down for instruction, together with confusing statements. But the wise man, by using his own judgment, will be able to profit by it.

Another description of the process:

Above cooking and distillation occur in the pot: below blazes the roaring fire. Afore goes the White Tiger, leading the way: following comes the formation of the gray liquid. The fluttering Red Bird flies the five colors. Encountering ensnaring nets it is helplessly pressed down and cries with pathos like a child after its mother. Willy-nilly it is put into a pot of hot liquid to the detriment of its feathers. Before half of the time has passed dragon scales appear with great rapidity and in great numbers. The five dazzling colors change incessantly. Turbulently boils the liquid in the Ting. One after another they come, irregular like the teeth of a dog. Stalagmites are spit out which are like midwinter icicles. Rocky hills appear with no apparent order, supporting one another. . . .

This is indeed a marvelous art that I am writing about. I am speaking with deliberation. This is meant to be transmitted to posterity through thousands of years for their reference. This to them should be as bright as the stars crossing the milky way and as sure as the rivers running into the sea. The aspirant should study this with diligence and care. Revelation will come to bring him enlightenment. Careful study will open the doors to the secrets. Nature's Tao shows no partiality, but reveals to those who are worthy.

In Pao P'u Tzŭ, Ko Hung (978) states that

> Wei Po-yang was the "Father of Alchemy," and had three disciples who went into the mountains to make medicines. When made, they first tried them on dogs to see if they were fatal or immortal in their effects. Dogs died when fed on them; one of the disciples ate one and he also died. Wei Po-yang also ate one and died, etc. When they were being put into their coffins they resurrected.[17]

Ko Hung or Pao P'u Tzŭ.—The Taoist alchemist and physician, Ko Hung (978) (about A. D. 281–361), was born at Chiang-ning-fu in Kiangsu. At some time after the year A. D. 326, he requested the Emperor Yüan Ti (1350) to send him to Kou-lou because cinnabar, which he needed for his experiments, could be obtained there from Cochin-China. He wrote two important medical works, as well as the pseudonymous Pao P'u Tzŭ, a treatise on Taoist alchemy, dietetics and magic which had considerable influence on the development of Taoist doctrines and superstitions.[18] A text of this work occupies six volumes or fascicules (three for the "Inner Chapters," three for the "Outer Chapters") of a recently printed edition of the "Collected Taoist Classics."[19]

Johnson[20] quotes from Pao P'u Tzŭ directions for the preparation of the pill of immortality:

> Take three pounds of genuine cinnabar, and one pound of white honey. Mix them. Dry the mixture in the sun. Then roast it over a fire until it can be shaped into pills. Take ten pills of the size of a hemp seed every morning. Inside of a year, white hair will turn black, decayed teeth will grow again, and the body will become sleek and glistening. If an old man takes this medicine for a long period of time, he will develop into a young man. The one who takes it constantly will enjoy eternal life, and will not die.

[17] Read, *loc. cit.*, trans. Yung.

[18] Sarton, *op. cit.*, p. 355.

[19] The Commercial Press, Ltd., Shanghai, China.

[20] Johnson, *op. cit.*, p. 63.

Another quotation[21] from the same work suggests that Pao P'u Tzŭ, like the Alexandrian alchemists, regarded the transmutation of metals as being accomplished by transmutation of color. "Whiteness is the property of lead. But if you cause it to become red, the lead will change into cinnabar. Redness is the property of cinnabar. But if you cause it to become white, the cinnabar will change into lead." Possibly the passage indicates a confusion between red lead and cinnabar.

Edkins[1] has argued that Chinese alchemy arose out of the fantastic side of Taoism and has supported his arguments, in part, by quotations from Pao P'u Tzŭ, which, he says, "contains an accurate account and obstinate defense of the system" as it existed in Ko Hung's time. The excellence of the translation, the inaccessibility of the *Transactions* in which it is published and the general paucity of material on Chinese alchemy make it worth while to reprint here *in extenso* that portion of the translation which relates especially to alchemy.

> We often hear the golden elixir spoken of, but people do not talk of it as being attainable in our own time: they all say that the genii of olden times only were acquainted with the elixir. Now the reason of this incredulity is, that in the current recipes for it, many errors and deficiencies exist. Formerly, Tso-yuan-fang (2028), after meditating profoundly, was accosted by a spiritual being, and presented by him with the "Book of the Elixir of Immortality" (Chiu-tan-hsien-ching). When the Han dynasty was falling, he withdrew from the troubles that then agitated the world to a mountain retreat. His pupil was my instructor, and from him I received several works on the elixir; others therefore have had no such advantages as I for knowing the secret of this preparation. For more than twenty years it has been in my hand. Alas! I could only lament, being poor, the want of means to make trial of it. Corn supports the life of the people; without it they die. Of how much more value must this wonderful medicine be! The golden elixir, the longer it is subjected to

[21] *Ibidem*, p. 74.

the action of fire, passes through transformations more and more remarkable. Gold when it is melted never diminishes; if buried in the earth, however long, it never rots. By taking these two substances as medicines, the human body may also be protected from decay, and acquire immortality. It is to external things that we must look for a preservation of life, just as by pouring oil on fire we increase its activity and prevent its destruction.

I write for those who have sought in vain for a teacher who could communicate to them the highest form of wisdom; for them I transcribe some parts of the works I possess on the golden elixir. . . . When vegetable matter is burnt, it is destroyed, but when the *tan sha* [cinnabar] is subjected to heat, it produces mercury. After passing through other changes, it returns to its original form. It differs widely therefore from vegetable substances, and hence it has the power of making men live forever, and raising them to the rank of the genii. He who knows this doctrine—is he not far above common men? In the world there are few that know it, and many that cavil at it. Many do not even know that mercury comes out of cinnabar. When told, they still refuse to believe it, saying that cinnabar is red, and how can it produce a white substance? They also say that cinnabar is a stone—that stones when heated turn to ashes; and how then can any thing else be expected of *tan sha*. They can not even reach this simple truth—much less can it be said of them that they have been instructed in the doctrine of the genii. . . . For the sake of those in these later times who should be willing to be taught, the sages of antiquity transmitted a method by which they might be freed from death and misery. Is it too much to make a trial of this method? If you should gain thereby only two or three centuries of life, would not this slight addition to your existence be far better than the fate of the mass of mankind? Many fear to attempt seeking after immortality, lest they should fail and expose themselves to ridicule, as the victims of folly and deception. But if they should resolve at all risks, to obtain only this doctrine of immortality for the benefit of mankind, and succeed in it in one instance, would not those who had laughed be themselves deservedly laughed at?

The medicine should be prepared on a mountain, in a lonely spot, only two or three being present. There should be fasting for one hundred days previously, and perfect purification of the body. The parties should be all believers in the doctrine; and persons who would ridicule the undertaking, should be kept in ignorance of it, otherwise the preparation of the elixir would fail. When it is made, the successful manipulator will, with all his family, become immortal. Common men refuse to adopt this method, preferring to use medicines which are vegetable substances, forgetting that, being subject themselves to decay and destruction when placed in the earth or near the fire, they can not give life to man. The nine preparations that can confer immortality on man are not what persons of the common stamp should ever see or hear of. Stupidly they seek after riches and honors, and these alone. Like walking corpses, they pass through the world.

This passage is followed by a description[22] of the nine preparations. Alum, quicksilver, sodium sulphate, potash and oyster shells are among the substances which are used. In another section, Pao P'u Tzŭ enumerates several substances which may be regarded as materials for the elixir of immortality. Cinnabar, he says, is the most efficacious, gold second, silver third and fourth ling chë, a plant which confers everlasting happiness. He names various precious stones, medicines and vegetable products, seventeen in number, which are effective elixirs of immortality, but not all of them are effective in the same degree.

T'ao Hung-Ching.—The Taoist physician and alchemist T'ao Hung-ching (1896) was born at Mo-ling, Kiangsu, near Nanking, in 451. Just before his birth, his mother dreamed that a green dragon issued from her bosom and that two angels came to her house with a bronze censer in their hands. At the age of ten years, T'ao Hung-ching read the writings of Ko Hung and began to "pound drugs" with a view to discovering the secret of immortality. He was a handsome man, seven feet four inches tall, an enormous reader and an excellent performer on the lute. Before he had attained to full manhood, he was appointed by the Ch'i Emperor Kao Ti (714) to be tutor to the imperial princes.

22 Summarized by Edkins but not translated at length.

He resigned that position in 492 and retired to the mountains in Hua-yang where he remained until his death in 536. He was known as the Hermit or the Saint of Hua-yang. He dwelt on the top floor of a three-storied tower, lodging his disciples on the middle floor and visitors on the floor below. The Liang Emperor Wu Ti (720) was among his visitors, before he mounted the throne; and, after his accession in 502, he offered to make T'ao his minister, but the latter refused to return to the world. The Emperor, however, consulted him on matters of importance, for which reason he was known as the "Minister in the Mountains." He passed his life in alchemical and similar research, practicing the method of breathing which is supposed by the Taoists to conduce to immortality, and trying to live without food. His chief amusement was listening to the sound of the breeze in the pine-trees. He wrote, or edited, one of the most important ancient treatises on materia medica, the Ming-i-pieh-lu. To the 365 drugs mentioned in the Shên-nung Pên-ts'ao (fourth century, B. C.), he added 365 others which had been recommended by the physicians of the Han and Wei dynasties. He wrote another treatise on materia medica, entitled Pên-ts'ao ching-chu, and other medical works. He wrote Tao-chien-lu, a treatise on famous swords, and edited, in or after 489, the Chên-kao, or "Declaration of the Genii," a work which is devoted to the magical and fantastic aspects of Taoism.[23]

Pi Shêng (1646) flourished under the Sung Emperor Jên Tsung (144), who reigned from 1022 to 1063. He was an alchemist and inventor, and devised, between 1041 and 1049, the art of printing with movable type. He used type made of clay and experimented with wooden type. The invention was later improved by an unknown person by the use of type made of tin, perforated and held in place by means of a wire. We have at present no information concerning his alchemical work.[24]

Tou P'ing (?) flourished in the first half of the eleventh century (?) and wrote Chiu P'u, a treatise on spirituous liquors which consists chiefly of brief notices regarding different kinds of liquor and celebrated distillers. His treatise may perhaps possess considerable significance, inasmuch as the art of distilling alcohol was probably unknown in Europe before the twelfth century.[25]

Conclusion

Chinese alchemy is a broad and largely unexplored field for study. The present paper scarcely scratches the surface of it. But it shows the sort of thing that will be found in it, and, we hope, makes clear the necessity for more detailed studies in this important chapter of the history of chemistry.

[23] Sarton, *op. cit.*, p. 436.
[24] *Ibidem*, p. 723.
[25] *Ibidem*, p. 723.

AERONAUTIC DEVELOPMENT

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SINCE the first flight by Orville Wright in a powered heavier-than-air machine, aeronautics has been in the course of development for a period of twenty-six and one half years. When we consider the magnitude to which the idea of the Wright brothers has grown and the fact that man has had a desire to fly like the birds almost from the beginning of time, this period is indeed a short one.

Although the principle and practicability of flight has been thoroughly demonstrated and established as something that was destined for the world to utilize for commerce and pleasure, the surface of great possibilities for aeronautics is just being scratched at the present time.

Three years after the dawn of the twentieth century, Orville Wright was carried off the ground for a few moments by a flying machine. Last year, over 25,000,000 miles were flown in scheduled operations by United States air lines, and nearly 160,000 passengers and 8,000,000 pounds of mail were transported over these lines. The passengers carried represented over three times as many as were flown the previous year, and the increase in the amount of mail carried was 100 per cent. Established route mileage of 36,000 in 1929 was more than double the miles in 1928, and the fact that miscellaneous commercial flying in this country increased from an estimated 60,000,000 miles in 1928 to 110,000,000 miles in 1929 is of special economic significance.

This splendid record serves only to indicate what may be accomplished in the next few years with properly coordinated development work on problems that continue to present themselves as aeronautics continues to make progress.

Congress, through the Air Commerce Act of 1926, delegated to the Secretary of Commerce the responsibility of encouraging and fostering the development of civil aeronautics in the United States and of regulating the use of aircraft in commerce. Soon after the passage of the act, the Aeronautics Branch was organized to carry out the details of the work. In order best to meet this assignment, the Aeronautics Branch has divided itself into three units, one dealing with air regulation, a second with the establishment and maintenance of airways and the third with aeronautic development. It is with this last-mentioned division that the Aeronautic Development Service of the Aeronautics Branch is primarily concerned.

The Aeronautic Development Service embraces all activities of the Commerce Department in connection with assisting communities in the selection and development of airports, the rating of airports, the promotion and correlation of aeronautic research, the publication and dissemination of aeronautic information, the publication of air navigation maps and airway bulletins and the general promotion work of the department looking toward the development of civil aeronautics.

An outstanding activity of the Aeronautic Development Service pertains to the development and improvement of aids to air navigation and the promotion of safety and comfort in flight. This work includes such activities as research on aeronautic radio, investigations on aeronautic lighting, wind tunnel studies, sound-proofing of airplane cabins and reduction of noise from engines and propellers, research on special airplane engine problems and investigations of

the strength of airplane joints and fittings.

Current work of the Aeronautic Development Service in the field of aeronautic radio includes the development of a convenient and reliable direction finder (radio-compass) for use on airplanes. This device will supplement the radio range beacon system of the federal airways by providing a means of navigation for pilots flying on independent routes. Experimental work is also being conducted on a number of problems having to do with the development of radio range beacons, such as adjustment of the directions of the several courses produced by the transmitter to fit the actual airways radiating from the transmitter; reliability tests on course direction as affected by such factors as lapse of time, time of day and distance from transmitter; the development of beacons giving simultaneously more than four courses from a single transmitter, and improvements in the receiving equipment. Also research is in progress on the simultaneous transmission of radio telephony and radio beacon service (using visual type indicator) on the same radio frequency. This includes the development of a transmitter which will send two types of signals without mutual interference.

In addition to such auxiliary radio problems as antenna design and ignition shielding, the service is also working on the development of a blind landing system for use at airports. Such systems, in general, include three elements, or their equivalent, to indicate to the pilot the position of the aircraft in three dimensions as it approaches and reaches the instant of landing. In the present experiments, lateral position (*i.e.*, the landing field runway direction) is given by a small directive beam of the same type as the beacon used for guidance along the airways but lower in power. Longitudinal position (*i.e.*, approach) is given by marker beams. Height is given by an inclined high frequency radio beam. This beam is directed on a small angle above the horizon and is used in such a way as to provide a very convenient gliding path for the landing airplane, beginning at any desired elevation and any desired distance from the landing field. The airplane does not fly on the axis of the beam but on a curved path whose curvature diminishes as the ground is approached and which becomes tangent to the landing area at a predetermined point.

Research is also in progress on the improvement of lighting devices at landing fields, such as wind indicators and boundary lights; the improvement of navigation lights and landing lights carried on aircraft; the study of landing field lighting requirements, including field methods for measuring low illuminations and photometric measurements on beacons, traffic signals and miscellaneous aeronautic lighting devices.

Aircraft engine research includes experimental work which has to do chiefly with perfecting mercury scales used to measure engine torque and developing improved methods of correcting the observed torque for the slip-stream reaction. This windage effect can be eliminated if it is possible to use an air-straightening grid of suitable design between the propeller and the engine. The effect of grid thickness, size of opening and over-all grid size are matters which can be determined only by actual experiments. The magnitude of the windage correction may also be determined by using another engine to spin the test propeller and measuring the torque due to the slip-stream above. Both methods must be tried out and checked by dynamometer calibration of the engine used.

Wind tunnel research includes the investigation of the stability of airplanes at low speeds and high stalling angles and the study of the effect of changes in the chord and span of ailerons on the rolling and yawing movements of air-

craft—at both low and high angles of attack. This work has a direct bearing on the control of airplanes at low speeds and high angles of attack and is a direct service to manufacturers, for its aids in determining the performance of a new type of airplane previous to actual construction. At the same time it advances the policy of the Aeronautics Branch of increasing safety in the air by affording information on the probable behavior of new types of aircraft.

Engineering research includes study of the various means of reducing the noise in the cabins of passenger airplanes and the general use of steel tubing—welded at the joints—in airplane construction. To date, the noise-reduction studies have met with much success in so far as they embody the insulation of the cabin. Studies of various types of muffling devices for engine exhausts and of methods of reducing propeller noise are under way. The general use of steel tubing welded at the joints, in airplane construction, has created a demand for more complete and reliable data on the strength and other properties of welded joints in structural members. This investigation has been undertaken as part of the program of the Aeronautics Branch in promoting safety in aviation.

The airport work of the Aeronautic Development Service falls into three main groups: (1) the direction and coordination of the work of the department related to assisting in the selection of airport sites and fostering the development of airports; (2) the promulgation of airport rating regulations and the rating of airports; (3) planning and preparation of airport publications.

This activity embraces conferences with municipalities and civic organizations desiring assistance in the selection of airport sites and requesting information regarding the requirements for the development of suitable airports. A small group of airport specialists are available for this work. These men are sent throughout the United States on carefully planned itineraries—the usual procedure calling for the inspection of a number of sites, perhaps a talk before a civic organization and a conference or series of conferences with officials interested in the development of the airports and desiring information regarding the requirements of the airport rating regulations of the Department of Commerce.

These specialists urge the importance of having experienced engineers make comprehensive studies and prepare plans for complete airport development, in order that every dollar invested in the project may be expended to the best possible advantage. It should be understood that the Department of Commerce representatives do not render this engineering service.

Another function of the Aeronautic Development Service relating to airports is that of rating airports upon application of the owner.

During the past twelve months, much time has been devoted to a study of the management aspects of airports and to a uniform system of field rules which will apply in whole or in part to airports all over the country. The need for such work is readily recognized in light of the fact that in the United States there are at present approximately 1,600 airports and landing fields in various stages of completion and some 1,100 airports proposed for early development.

Still another important activity of the Aeronautic Development Service is the preparation of maps and charts for air navigation. The maps compiled are published on a scale of 1 to 500,000, or about eight miles to the inch. The maps published to date, usually referred to as "strip maps," cover strips eighty miles in width and from two hundred to four hundred miles in length—the size of each sheet being eleven inches wide and twenty-four to forty-eight inches long, a

very convenient form and size which can be readily folded for use by the pilot. This section has recently started work on the publication of a series of sectional area air navigation charts covering the entire United States.

The material used in the compilation of the air navigation maps is taken from various sources. Among these are the topographic maps of the U. S. Geological Survey; the contour lines forming the boundaries for gradients of elevation on airways maps are almost always taken from these topographic maps.

After an air map compilation has been made from the best available material, photographic copies mounted on cloth are flight checked. This work is done by a trained engineer who goes as an observer with a pilot of the Aeronautics Branch. A number of trips are made back and forth across the region represented until the whole area is covered. The compilation is then corrected accordingly and lithographic impressions are made on a scale one fourth larger than the compilation. One of these sheets is inked for each color to be printed on the map. When the inking is finished, the drawings are again reduced by photography to the original scale and the negatives are used to prepare the aluminum plates for printing the edition. The maps are printed in color to express such various features as streams, elevations, airports, flight courses and magnetic variations.

The Aeronautics Branch has organized a number of special research committees under the chairmanship of the director of aeronautic development for the purpose of investigating certain problems as follows:

The fact-finding committee organized to determine the effectiveness of the automatic application of water in controlling airplane hangar fires has just completed an extensive series of fire tests and is now engaged in the preparation of its report.

The committee on standard signal systems for airports is conducting studies looking toward the development of standard signal systems, suitable for both day and night use, for controlling traffic on and in the vicinity of airports and for communicating special information to pilots.

The liaison committee on aeronautic radio research has made a survey of aeronautic radio research now in progress and of those radio problems the solution of which will assist in bringing about the highest degree of safety and reliability in air transportation. This committee has just submitted its first report to the Assistant Secretary of Commerce for Aeronautics.

The committee on airport zoning and eminent domain is making a study of those problems having to do with the protection of the flying public against hazards that might be developed in the vicinity of airports.

The committee on airport drainage and surfacing is studying the problems involved in airport drainage and surfacing, and collecting and correlating available data and experience with the object of presenting a report that will serve as a working-tool in the hands of engineers engaged in the development of air terminals.

As the point of contact between the Aeronautics Branch, the aeronautic industry and the general public, the Aeronautic Development Service is charged with most of the promotional duties covered by the Air Commerce Act of 1926. Specifically, these duties include the preparation and publication of the *Air Commerce Bulletin,* a semi-monthly periodical, and more than a score of permanent aeronautic publications on important phases of aeronautics, the collection and dissemination of information pertaining to civil aeronautics, the preparation and publication of airway bulletins, the compilation of statistics regarding the manufacture and operation of civil aircraft, including accidents, and the maintenance of an aeronautics reference library.

The *Air Commerce Bulletin* is sent to more than 12,000 readers who have specifically requested it. This bulletin is also circulated through aeronautical clubs, libraries, airports and other seats of flying activities. Among other things, it carries official notes to pilots, manu-

facturers and operators of aircraft; information pertaining to new regulations and air traffic rules; statistics on operation, miles flown, accidents and their causes; lists of aeronautical lights certified; general notes on the progress of civil aeronautics at home and abroad; lists of air routes in operation; notes on the progress of airway lighting, radio and other aids to air navigation; articles and tabulations on airport and airway development; state laws and municipal ordinances; existing and proposed airports; lists of official publications available, and other constructive information of an authentic and authoritative nature relating to civil and commercial aeronautics.

In connection with this phase of its activities, the Aeronautic Development Service procures, compiles and analyzes all statistical data for the Aeronautics Branch—including data covering aircraft production, aircraft operation, aircraft accidents and aids to air navigation; collects facts and figures for all statistical bulletins of the Aeronautics Branch, including the Aeronautics Trade Directory; distributes all publications and printed forms of the Aeronautics Branch; interviews persons desiring general information, and handles correspondence that does not pertain to the technical phases of the work of the Aeronautics Branch.

Of steadily increasing importance is the work of preparing and issuing airways bulletins containing descriptions of airports and information regarding other air navigation facilities in the United States. These bulletins, which are distributed to a mailing list of approximately 3,000 individuals and organizations, are illustrated loose-leaf sheets describing airports, Department of Commerce intermediate fields, airways, air markings, meteorological conditions and other data essential to air navigation. The bulletins describing airports carry in each case two maps, one of the airport itself showing the immediately surrounding terrain, and the other showing the airport's location with respect to nearby railroads, rivers and the nearest city. In addition, these bulletins give the name of the airport, its class, latitude and longitude, altitude above sea-level, description of surface and runways, obstructions, marking and identification, lighting, accommodations, meteorological data and other information desired by pilots or operators. To date, 983 airways bulletins have been issued.

The Aeronautics Reference Library of the Aeronautics Branch is also a part of the Aeronautic Development Service. On file in this library there are now 471 bound volumes and more than 10,000 domestic and foreign magazine articles, pamphlets and reports which have been catalogued for ready reference. Complete sets of all government aeronautical publications as well as an extensive file of news clippings are maintained. A semi-monthly bulletin is published listing references of important articles indexed by the librarian from current publications received. Close cooperation is maintained with the engineering and technical units in the collection of data on the latest engineering developments.

The program of aeronautic development now being carried out by the Aeronautics Branch is the result of a careful study of the more important phases of aeronautics that are in need of immediate attention. As the aeronautic development work of the Aeronautics Branch goes forward from day to day, and as problems of the moment are disposed of, new ones arise to take their place. The Aeronautics Branch is aware of its obligations under the Air Commerce Act and is endeavoring to discharge them to the complete satisfaction of the public.

AIR REGULATION

By GILBERT G. BUDWIG

DIRECTOR OF AIR REGULATION DEPARTMENT OF COMMERCE

THE Air Commerce Act of 1926 charges the Secretary of Commerce with the promotion of civil aeronautics, and also with its regulation.

Prior to the passage of this act, aeronautics regulated itself. This meant that the judgment of the pilot and mechanic was the law of the moment. As aeronautics continued to grow and as its value in the field of transportation became more and more evident, Congress, in 1926, felt the time had arrived for a standardization and uniformity of operation of aircraft and airmen.

Accordingly it granted the regulatory powers to the Secretary of Commerce. The spirit of these regulatory powers may be set forth in a few words, "airworthy aircraft operated by competent airmen." From this initial starting-point, two courses were laid out for the realization of this valuable motto for the development of aeronautics.

They were licensed aircraft and licensed airmen. Both are accomplished through initial and periodic examinations. The first examination determines the qualifications of the applicant, be it aircraft or airman, while the succeeding ones determine the right of the license holder to continue in good standing.

The license for both airman and aircraft places a federal stamp of approval on the holders. The license gives testimony to the fact that a number of rigid requirements have been met to the satisfaction of the Department of Commerce, and as long as the holder of the license continues to observe these requirements he will continue to receive the endorsement of the department.

The regulations require that all aircraft and airmen engaged in interstate commerce shall hold a Department of Commerce license. Originally this provision opened the door for the operation intrastate of aircraft and airmen who could not qualify for a federal license. The government has no jurisdiction over aircraft activities within a state as long as they remain within that state's borders. The moment an unlicensed pilot or plane, engaged in commerce, crosses the border in pursuit of that commercial venture, he becomes subject to the federal law.

Many states, recognizing that aircraft and airmen who can not meet the requirements of the Department of Commerce for licenses are endangering their own lives and those of the innocent public, have adopted laws requiring aircraft and airmen to hold the Department of Commerce licenses regardless of whether they engage in commercial ventures within the state or interstate. Thus the day of the unlicensed pilot and plane is on the wane.

Prior to the Air Commerce Act of 1926, there were many ideas current as to how aircraft should be built. As there was no supervision over the design and construction of these aircraft, as there were no recognized standards followed in all cases, the task of licensing aircraft as being airworthy was exceedingly difficult.

In an effort to save the time and money of the manufacturers as well as to protect the public against aircraft designed and built contrary to the generally recognized sound methods then in existence, the Department of Commerce, with the cooperation of the industry, drew up certain engineering requirements to be met before a plane could be

produced in quantities for use in interstate commerce.

These standards now are observed by all aircraft manufacturers seeking approved type certificates for their products. Once the certificate is granted, the manufacturer may build unlimited numbers of these craft subject to supervision during their construction period and flight testing after their completion by inspectors of the Aeronautics Branch. These types are then eligible for license.

In this way, aircraft designed by persons with a smattering of aeronautical engineering knowledge or no knowledge at all, and aircraft constructed in a woodshed with a saw and hatchet, are discouraged and have been discouraged to such an extent that they now are a memory of the pioneering days.

As for the airman, experience has developed the system of licensing in use to-day which is serving the needs of aeronautics to the best advantage. A person desiring to become a pilot first must obtain a student permit which is issued by the authorized Department of Commerce medical examiner if the applicant satisfactorily passes the required physical examination.

His student days over, the applicant takes his examination for the private pilot license, which includes a rigid written as well as flying test. The holder of a private pilot license is not permitted to engage in interstate air commerce.

To the private pilot there are available higher grades of licenses—limited commercial, industrial and finally the transport pilot license. The limited commercial and industrial licenses involve certain restrictions as to carrying passengers, but the transport pilot license permits the holder to fly any type of licensed plane and to carry passengers in any plane that he has demonstrated his ability to operate before a Department of Commerce inspector.

From the beginning of its regulatory activities, the Department of Commerce made plans leading to airworthy aircraft from their inception. No authority existed under the act to follow the same course with respect to the pilot. It was not until early last year that such authority became available through an amendment to the act which gave the Secretary of Commerce authority to approve flying schools as to the adequacy of the course of instruction, the suitability and airworthiness of the equipment and the competency of the instructors. Examinations and inspections leading up to approved flying schools are made only upon the application of the institution.

There now are more than two score approved flying schools in the United States that have been examined and constantly are the subject of federal inspection with the view to seeing that they continue to adhere to the minimum requirements established by the department for approved schools. Among these requirements are the provisions that instructors must hold a special license as flying and (or) ground instructors. Pilots giving instructions at schools not approved are required to hold the transport license.

Thus the department has been able, in a great measure, to assist in bringing about the airworthiness of aircraft and the competency of airmen from their inception. As aeronautics progresses, this phase should develop to a point where there will be uniformity and standardization of the development of aircraft and airmen in conformity with the best and time-tested standards.

An important feature of the airworthiness of aircraft is its engine. The Aeronautics Branch requires that all airplanes engaged in interstate commerce shall be equipped with power plants of a type bearing federal approval. The engines for aircraft use, therefore, must pass type tests as to reliability pre-

scribed either by the Department of Commerce or by the Army or Navy before they can be certified.

Some of the other phases of air regulation are:

The examination and licensing of mechanics
The transfer of title to aircraft assigned Department of Commerce markings
The issuance of certificates of airworthiness for export to aircraft to be exported to foreign countries having reciprocal agreements with the United States
The validation of such certificates and the maintenance of all files and records pertaining thereto
The handling of legal phases of enforcement of the Air Commerce Regulations
The enforcement of violations of the Air Commerce Act, the Air Commerce Regulations and the Air Traffic Rules
The assessment of penalties thereunder
The determination of the causes of civil aircraft accidents

An indication of the volume of work in air regulations may be gained from the fact that during the past fiscal year which ended June 30, 1930, a total of 64,806 licenses, license renewals, title transfers, export certificates, identifications and student permits were issued as against 42,408 for the previous year. This represents an increase in volume of work over the preceding year of 153 per cent.

During this same period, pilot licenses renewed increased 195 per cent. over the year before; pilot licenses issued, 197 per cent.; student permits issued, 133 per cent.; aircraft licenses issued, 145 per cent.; aircraft licenses renewed, 309 per cent.; transfers of title completed, 147 per cent.; export certificates issued, 114 per cent.; identification marks assigned, 100 per cent.; mechanics licensed, 113 per cent.; mechanics licenses renewed, 2,909 per cent.

The Aeronautics Branch has just taken what is regarded as the most important step since it undertook the licensing of aircraft and airmen. Reference is made to the new regulations governing the operation of scheduled interstate air passenger services, which became effective May 15. The fundamental requirements of these new regulations are as follows:

AIR COMMERCE REGULATIONS GOVERNING SCHEDULED OPERATION OF INTERSTATE PASSENGER AIR TRANSPORT SERVICES

1. *Law of, scheduled operation of interstate passenger air transport services.*

The Secretary of Commerce shall by regulation . . . provide for the issuance and expiration, and for the suspension and revocation, of registration, aircraft and airman certificates, and such other certificates as the Secretary of Commerce deems necessary in administering the functions vested in him under this act. (Sec. 3 (f).)

2. *Application of the law.*

For the purpose of conducting the scheduled operation of passenger air transport services in interstate air commerce, as defined by the Air Commerce Act of 1926, it shall be necessary for any person, firm, copartnership or corporation to obtain from the Secretary of Commerce a certificate of authority to operate such service.

3. *Issuance of certificate.*

Before such a certificate of authority will be issued by the Secretary of Commerce, application therefor shall be made by the person, firm, copartnership or corporation proposing to conduct or to continue the class of service covered by section 2. The application shall be made in such manner as the secretary may prescribe. This certificate, if issued, shall be conditioned upon compliance with the Air Commerce Act, and the Air Commerce Regulations, including the specific requirements set forth herein.

4. *Aircraft and airmen.*

(*a*) Aircraft shall be provided with suitable instruments and equipment and shall be properly adaptable to the nature of the service involved, and to the conditions attendant thereon.

(*b*) An adequate number of qualified airmen shall be employed who shall be fully competent in all phases of the particular operation, including the use of equipment, devices, accessories, and other aids incident to the operation for which the

certificate is issued. The Secretary of Commerce may, in his discretion, require that the crews of the aircraft employed shall include such qualified personnel, other than the pilots in command, as may be necessary safely to carry out the particular operation.

5. *Maintenance of equipment.*

All aircraft, including engines and equipment, shall be maintained to the highest degree of operating efficiency, and to this end certain fixed periods will be determined by the Secretary of Commerce for the inspection, repair and overhaul of aircraft, engines, instruments and equipment.

6. *Airways and air navigation facilities.*

All airways or routes over which scheduled operations are conducted or proposed shall be provided with such air navigation facilities as are considered necessary by the Secretary of Commerce in the interest of safe and reliable operation of the particular service involved or to be undertaken.

7. *Ground organization.*

The operator shall provide to the satisfaction of the Secretary of Commerce an adequate and properly qualified ground organization to administer efficiently all phases of the ground operation, including maintenance.

8. *Flight clearance.*

Each scheduled flight shall be authorized, delayed, suspended or canceled by competent officials designated by the holder of the certificate of authority. The manner and form in which this is accomplished will be prescribed by the Secretary of Commerce.

9. *Operations instructions.*

The Secretary of Commerce may from time to time prescribe uniform instructions pertaining to operations, the issuance and publication of which by the holder of the certificate of authority shall be mandatory, and such instructions shall be made conveniently available for the information of all passengers in the manner and form prescribed by the Secretary of Commerce.

10. *Ground for revocation or suspension of certificate.*

The certificate of authority may be suspended or revoked for:

(*a*) Violating the Air Commerce Act or the Air Commerce Regulations, including the specific requirements set forth herein.

(*b*) Failure to make any proper and seasonable report which may be required by the Secretary of Commerce.

(*c*) Making false statement in application, or information accompanying the application for said certificate, or in any report required by the Secretary of Commerce.

(*d*) Conducting operations contrary to the public safety and interest.

(*e*) Using or displaying said certificate for fraudulent purpose.

11. *Savings clause.*

These regulations shall take effect midnight May 15, 1930. Air transport services subject to these regulations may continue to operate until midnight, July 15, 1930, on or before which date said air transport services shall file an application for a certificate of authority with the Secretary of Commerce. Upon receipt of said application, the Secretary of Commerce may issue a temporary letter of authority to operate, pending inspection, in the manner and form prescribed by said secretary.

CLARENCE M. YOUNG,
Acting Secretary of Commerce

Approved May 2, 1930.

Obviously, they require interpretation and detailed interpretations now are being prepared. When placed in full operation, the requirements are expected to bring about even higher records for safety and reliability of scheduled passenger air transport.

The Aeronautics Branch found this action necessary in order to standardize the various ideas of air transportation that develop from time to time. There will be conservative operators, liberal operators and operators not aware of the details necessary to make for safe and reliable service. The standard of minimum requirements adhered to will give air transportation the same uniformity of operation as is now enjoyed by the major railroad and steamship lines.

NATURE VERSUS NURTURE IN THE DEVELOPMENT OF THE MIND

By Professor S. J. HOLMES
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One meets more or less frequently with expressions of the opinion that recent investigations in psychology have demonstrated the overwhelming importance of environment as compared with heredity in the development of the mind. There is perhaps no subject of more vital concern to the eugenist than the heredity of mental traits. If the mental differences among human beings are almost entirely the result of varied conditions of life, the worries of the eugenist over the super-fecundity of the subnormals and the low birth-rate of the intellectuals would really have no adequate foundation. Many people would like to believe that this is true, for if it is true we may console ourselves that the most serious of our so-called dysgenic ills will gradually recede before the triumphant march of social reform.

That there is still a remarkable amount of divergence of opinion over the relative importance of nature and nurture in the development of mental traits is doubtless due in large measure to the fact that mental traits are demonstrably influenced by both hereditary and environmental factors, and that our problem is one of the relative influence of two forces, always intimately associated, neither of which is capable of very precise measurement. Another potent cause of disagreement is the fact that a considerable number of those concerned with psychology, education and the social sciences have a very imperfect grounding in the principles of modern genetics. Then we have various kinds of emotional bias which influence opinions on the subject to a marked degree. There is the theological bias which leads people to regard with disfavor the doctrine that traits of the mind obey the same laws of heredity that obtain for the material body. A probably stronger bias in these days arises from the varieties of political and social philosophy whose votaries scent a danger in the doctrine of the natural inequality of man. We have also what may be called the humanitarian bias, commonly found among those engaged in the uplift of their fellow creatures, which predisposes people to attribute human ills, so far as possible, to remediable causes. The so-called fatalistic teaching of the hereditarians is regarded as a sort of challenge to the efficacy of their efforts at social improvement.

As a result of many kinds of bias, complexes, phobias and idola we have a large body of interested and often aggressively good people who are eager to welcome anything which seems to weaken the position of the hereditarians. Recent investigations have supplied a large amount of material bearing upon the question at issue. Not only have many contributions been made by the biologists, but a large number of researches are described in the rapidly swelling literature on educational psychology.

As a preliminary to the discussion of these results it may be desirable to trace briefly the development of our topic. The first substantial contribution to our knowledge of the inheritance of mental ability was Francis Galton's well-known book on "Hereditary Genius." By the use of impartial statistical methods,

Galton conclusively proved that superior mental ability runs in families, and that the more eminent a person is the greater the number of eminent relatives who will on the average be found in his family. Further evidence in support of this general conclusion was furnished in his book on "English Men of Science" and in a work by himself and Schuster on "Noteworthy Families" based on a study of the family histories of fellows of the Royal Society.

The work of F. A. Woods on "Heredity in Royalty" showed that in the favorable surroundings of royalty there are differences in the mental abilities of families which are very much like those which occur in the general population. Parent-offspring and fraternal correlations were discovered by Pearson and his coworkers, who found a close resemblance in scholastic records between parents and offspring and between children in the same family. These correlations were roughly about the same as those for various physical traits, which average about 0.5. It was contended by Pearson that since mental traits run in families to about the same degree as traits such as eye color and cephalic index, which are admittedly little affected by environment, we must conclude that it is heredity which affords the explanation of all these cases of familial transmission. When abilities came to be measured by mental tests as well as scholastic records very similar parent-offspring and fraternal correlations were reported by a number of investigators.

In the light of a large body of knowledge which is now accumulated, no one with the least knowledge of the facts can deny that mental ability, as gauged by available methods, shows a strong tendency to run in families. The environmentalists maintain that this tendency is no proof of the inheritance of mental traits; the relation can as well if not better be explained as the effect of the social, educational and other advantages which fall to the lot of the children of more distinguished parents. There is no doubt that in most cases circumstances favorable for education, if not mental development, are more frequently found in families with a tradition of culture. It is very pertinent to inquire, therefore, whether or not these influences can account for the whole of the resemblance between parents and offspring in respect to intelligence and other functions of the mind. Here is a problem of the relative influence of two factors each of which is capable of accounting for variations in mental development. Consider, for instance, the Edwards family, which has been so much discussed in connection with our present problem. The descendants of Jonathan Edwards include a surprising number of people who have acquired a high reputation for intellectual achievement. But the children in these families had the advantage of good schooling, a stimulating home environment and a certain amount of social prestige which aided them in attaining worldly success. Would the families of their undistinguished neighbors have made the same reputation under just the same conditions? From what one knows of heredity and the influence of environment one might judge they would not, but there is no way in which the effects of heredity and environment can be separated in such a case in any clean-cut way. Parent-offspring or fraternal correlations can not be taken as a measure of the extent of hereditary resemblance without begging the question at issue. All that such correlations prove is the fact of familial resemblance, and they prove nothing directly as to the cause of this resemblance. We do not doubt the correctness of the genetic explanation in the case of eye color or polydactylism because there are no traditional environmental influences which would tend to cause this relationship. But when it

comes to mental development we are in a different position. Our means of measuring heredity fail us, for whenever we say that a given difference in mentality is due to heredity the environmentalist may challenge our statement and claim that it may be due to environment, or at least that we can not prove that it is not. And if one is under the influence of any of the several kinds of bias to which I have alluded he can still cling to his interpretation and defend it by arguments, however unconvincing these may be to the hereditarian. Several writers who have touched upon this theme consider that we have arrived at an *impasse,* and regard the solution of the problem as practically hopeless. The situation is, I believe, far from being as bad as this, and, unless I am greatly deceived, is showing distinct signs of clearing up. But it should be stated that there is not entire agreement as to which position is being strengthened by the results of recent investigations.

In a recent book on "The Behavior of Young Children of the Same Family" Miss Weill informs us that

> Scientific thought wheeled from an environmentalist point of view during the latter half of the nineteenth century, to a hereditarian and more fatalistic one, until the convergence of laboratory experiment, investigation of the causes of criminality, behaviorism, psychoanalysis, sociology, endocrinology, mental hygiene and child psychology showed that the springs of conduct lie in the early years of childhood, especially in the preschool period, and that environmental forces acting on this plastic material are able to mold it practically at will.

Miss Weill's book is based on several cases of problem children coming before the Habit Clinic of the Massachusetts State Division of Child Hygiene. When the environment of children living in the same family was investigated it was found that what superficially might seem to be the same surroundings for all the children was really far from being so. Differences of age, attitudes of parents and other children and many other factors create varied influences which, in the opinion of the writer, adequately account for the pronounced differences often manifested by the children of the same family. It is not denied that in certain cases hereditary factors play an important rôle, but the effort is made to explain everything in terms of environment wherever possible. In the case of the Sadnow family, for instance, it was pointed out that varied ages and interests keep each child in a different environment, and that in the case of the aberrant member, Micha, who it seems was very much of a spoiled child, "the environmental differences here are so strong that they may well be considered the cause of his behavior anomalies, and of the difference of his reaction to the family situation." An improved régime together with some wise counsel as regards discipline was said to have conduced considerably towards making Micha a better boy. Let us hope so. But even if Micha should turn out to be a most exemplary person, we are by no means justified in ruling out a possibly important influence of heredity. Where we are dealing with modes of response which can be readily conditioned even at an early age the separation of hereditary differences in appetites, aversions and other fundamental drives from the varied effects of early training is a matter of much difficulty. A study of the differences in disposition between identical and fraternal twins affords some interesting material in this connection, but the environmentalist may contend that ordinary, or fraternal, twins by virtue of their differences soon get into different relations with their environment and come to experience very unlike reactions from their associates.

In the study of problem children to which I have referred it is stated, apparently without sufficient appreciation of its bearing on the problem, that the parents of these children showed a large amount of neurotic disorder. "The large majority of the cases, however, thirteen of the seventeen, come under the classification of mental disability. Of these thirteen, one case shows stupid parents; one case a bad-tempered father and a yielding mother, and eleven, neuroticism in one or both parents."

Under such conditions one would expect to find as a result of Mendelian segregation a good deal of hereditary variability in dispositional traits among the offspring, and much of the kind of heredity which would predispose children for candidacy in a habit clinic. Environmental factors were doubtless varied and often unfavorable for the unfortunate children who were investigated. But under the circumstances, to claim that the results described demonstrate the overwhelming influence of environment as compared with heredity is quite unwarranted.

Perhaps the most extreme environmentalist position is occupied by Dr. J. B. Watson. This writer gravely informs us that "there is no such thing as an inheritance of capacity, talent, temperament, mental constitution and characteristics. These things again depend on training that goes on mainly in the cradle." We only inherit structures. "Habit formation starts in all probability in embryonic life and that even in the human young, environment shapes behavior so quickly that all the older ideas about what types of behavior are inherited and what learned break down." Dr. Watson, whose conception of heredity seems to be very different from that of the modern geneticist, is led to adopt a position which is open to all the objections which have been urged against the discarded teachings of Locke. For him the mind is a *tabula rasa* upon which experience writes all the contents. Barring certain obvious differences in physique all babies are supposed to be practically alike—all of them are plastic material which the skilful manipulator can mold into any form that is desired. Every one knows that young children readily acquire habits good and bad and that they can be inspired with fears and phobias in regard to many objects, but if Dr. Watson were able to demonstrate that he can alter the intelligence quotient of a child as little as twenty points there would be more basis for his extravagant claims. Even very young babies acquire conditioned responses and soon learn to tyrannize over their mothers and nurses. As a result of studies on early infancy we are acquiring much more accurate knowledge of the effects of experience in molding the character and disposition of children. But so far as I can discern, we have learned nothing which, in principle, was not familiar to our grandmothers. And if our grandmothers had told us that because it is quite easy to spoil children therefore there is nothing in mental heredity, their argument would have precisely as much cogency as that of Dr. Watson.

In the field of emotional reaction, habit formation and the development of principles of conduct the potency of environmental influence has been recognized for centuries, and I am not aware that it has ever been denied. Yet we know little of the extent to which affection, for instance, can be cultivated or suppressed, or, barring ill health, how far the disposition or temper of an individual may be changed under varied external conditions. We observe marked differences in temper and disposition appearing among members of the same family even from an early period, and under conditions which point strongly to initial differences in hereditary make-up. The environmentalists

always have some sort of an explanation to fall back upon, however far-fetched it may appear. Their argument takes this general form. Since grandmother spoiled Johnny by giving him whatever he wanted whenever he cried, how do you know that the very different traits of Mary and Lucy might not have had their cause in some early experience which produced a profound effect at a particularly impressionable period of their lives? Not knowing all the events in the history of each girl or just how each was affected by all her varied experiences, one is naturally unable to satisfy the environmentalist on this point.

The environmentalist argument is very much like that of a gardener who would claim that since soil and cultivation make such striking differences in the growth of plants, the matter of possible differences in seed can safely be ignored. In the development of character traits cultivation, as in plants, produces its obvious results, but our measures of the effects produced are so inexact and our means of comparing the relative influence of heredity and environment are so imperfect that no very definite conclusions can at present be drawn.

When we are dealing with the development of intelligence, however, we are in a better position. All the studies on the inheritance of intelligence are based on the assumption that we are concerned with something whose differences can be measured and compared. Galton made achievement and reputation a basis for a rough gradation of degrees of mental development. In other studies scholastic records or teachers' estimates of intellect were employed, and in recent studies use is commonly made of the intelligence quotient, or ratio of mental age to chronological age which is given a definite numerical expression. Every one admits that measures of intelligence are not always exact. Doubtless intelligence itself varies with the state of health, the emotional attitude and many other influences which fluctuate from day to day and from hour to hour. But nevertheless intelligence, however we may define it, is something which can be measured with a fair degree of accuracy.

One very striking finding of the numerous investigations on mental measurement is that there is a fairly definite limit to the growth of intelligence at from sixteen to eighteen years. Let us consider the meaning of this simple fact. If experience alone is responsible for the growth of intelligence there seems to be no reason why intelligence should not continue to grow as experiences accumulate throughout the greater part of life. The course of mental growth, like the course of physical growth which it so closely accompanies, must, therefore, be largely determined by internal causes. We may check or accelerate our physical growth in a number of ways, but except in extreme cases the changes produced are relatively slight. We can not make a man stop growing at ten or keep him growing until he is seventy. (I am disregarding here the accumulation of fat, which has its psychical counterpart in the accumulation of mere information.) One may keep on growing in knowledge or even in wisdom, but intelligence has pretty definite limits which are practically unchangeable. This fact does not harmonize at all with the doctrine that intelligence is not inborn but created as the result of experience.

Another highly significant result of mental testing is the fact that intelligence not only varies enormously among individuals, but the intelligence quotient is fairly constant in a given individual during successive years. The constancy of the IQ obtains for all degrees of intelligence from that of the feeble-minded to that of the very superior child with a grade of 140. Minogue found that among 441 feeble-

minded children who gave a very low initial rating, 71.7 per cent., tested from two to ten years later, varied less than 5 points; 91 per cent., less than 10 points, and that there was rather more of a tendency to deteriorate than to gain in intelligence scores, 4.8 per cent. showing a gain and 23.6 per cent. a loss. A similar tendency has been found in 200 cases by Bonnis.

Miss Otis has endeavored to improve the intelligence of feeble-minded girls over sixteen and found that the scores were raised somewhat "due more to changes in vocabulary score and understanding than to change in memory span or reasoning ability. . . . The gain in the reasoning tests could not be estimated, for there is hardly any success in these reasoning tests for any of the forty girls. . . . If the reasoning ability is absent there seems to be no way of training it in."

Turning to individuals of superior intelligence we find that, as a rule, a high IQ is manifested early in life and is consistently maintained at a high level. In a report of a follow-up study of a group of seventy-three children having an IQ of 136 or more in 1921–22, Duff found that, as compared with a group of controls with an average IQ of 100, the highly intelligent children were doing very creditable work; a larger percentage than the controls went to secondary schools, and 55 per cent. won prizes in the secondary schools, while no prize fell to the lot of the controls except one for attendance. Since some of the control group went on to secondary schools while some of the intelligent students did not it is of interest to compare these two classes. The intelligent group who were not in secondary schools were superior to the controls who were in these schools in spelling, adequacy of expression, quality and quantity of reading and in ambition. Of the control group none passed the school certificate, and only one reached the stage of attempting it. Of the intelligent group in secondary schools thirty passed the certificate and seven failed; ten changed schools; two were too young to try the examination, and two were lost from the record.

One of the most extensive investigations of superior children is that carried on by Dr. Terman and his associates on one thousand gifted children in California schools. The selection was made on the basis of intelligence scores of 140 or higher, a grade attained by less than one half of 1 per cent. of the school population. As a rule these superior children were of good vitality, interested in sports, socially adaptable and quite far from being the one-sided freaks that children of superior mentality are often supposed to be. Their ability was general rather than special, and their superiority was manifested in most cases in the preschool age. In school they had no advantages over the rank and file. In fact they received less attention than the dullards, as superior children generally do. They were helped a little more at home and in some cases they received a little more instruction than the ordinary child in preschool years, but there was nothing in their home environment which gave any adequate explanation of their superiority in mental tests. Information collected two years later showed that these children still possessed a marked superiority over their fellows. Whatever formed the basis of the higher attainments of these children was a persistent characteristic which manifested itself from an early period and behaved very much like an inherited trait.

It might be claimed that environment produced its effects upon these children while they were very young, for there has come to be a tendency to emphasize the cradle experiences of children as powerful factors in their future career. But whether it was the quality of milk

they received, the amount of orange juice or the patterns of the wall-paper they gazed at which exercised so marvelous an influence upon the development of their minds must be left to the environmentalists to ascertain. Here we need the illuminating wisdom of Dr. Watson.

But how about ancestry? To a large extent the fathers of these thousand gifted children were found to follow pursuits which required more than the average mental ability. Relatively the largest proportion of the fathers came from the professional classes. A considerable number were business men. A smaller number were skilled artisans, while less than 1 per cent. were unskilled laborers. In the pedigrees of these children there were many noteworthy names in English and American history, and the surprising fact was revealed that nearly one fourth of the individuals in the Hall of Fame were found in the ancestry of this group.

Evidence of the strong influence of heredity is also furnished by Cobb and Hollingworth's studies of the siblings of children testing from 135 to 190, with an average of 154. The average grade of the siblings was 129, and their tests ranged from 96 to 173. The siblings of children testing over 150 averaged 132.8, while the siblings of those testing from 135 to 150 averaged 124. Thirty cousins gave an average score of 127.

Correlative to the preceding studies of gifted children we have the interesting investigations of Cox, who, starting with adults who had achieved greatness, endeavored to ascertain from what kind of children these geniuses developed. From a variety of biographical sources an effort was made to gauge the IQ of these children. However successful this effort may have been—and the figures should be regarded only as a rude approximation—the striking fact is clear that great men come predominantly from children who from an early period manifested unmistakable signs of superior intelligence. Great men do *not* come from dull boys. We may generalize the results of researches on the constancy of the IQ by saying once stupid always stupid; once intelligent always intelligent. If the environmentalists could show that nurture is capable of developing intelligence to the extent of converting an individual with an IQ of 80 into one with 140 and that such transformations were matters of common occurrence he would have a fair basis for the contention that education and opportunity can account for the whole resemblance that is found among members of the same family. But even then his case would not be demonstrated. I might show that the proper cultivation can make very great changes in the growth of peas, but this would not exclude the possibility of my having the seeds of both tall and dwarf varieties in my stock. In the field of intellectual development, however, it has not been shown that much change is even possible. It is doubtful that if the intelligence of an individual is fairly tested it can be raised as much as twenty points. If good intelligence does not come by the grace of heredity there is no way in which it can be made.

Evidence supporting this conclusion is coming in from a variety of sources. Through studies made on groups of children under comparable conditions it has been shown that similarity of treatment does not reduce original dissimilarities, and that giving all students the best possible means of developing their capacity tends rather to increase than to diminish their differences in achievement. Some interesting work has been done with foster children who were adopted before they were one year of age. The intelligence of these children was found to resemble that of their real parents whom they had scarcely seen much more than

that of their foster parents with whom they were continually in contact. Those children who were adopted in better homes gave somewhat higher intelligence scores, and since with children adopted at so early an age there was probably little or no selective placement this improvement may fairly be attributed to environment.

Interesting side-lights upon the problem of nature and nurture have been furnished by studies on the mental resemblance of identical and ordinary, or fraternal, twins. Identical twins are in all probability derived from a single fertilized egg and hence have an identical heredity. So far as they have been studied the intelligence scores of identical twins show a remarkable degree of similarity, although there seems to be a wider divergence in character traits and disposition.

It is not improbable that different mental traits, like different physical traits, are very unequally affected by surrounding conditions. Environment may change the color of one's skin several times as much as the color of one's eyes. It may affect sweetness of disposition and adherence to moral standards of conduct much more than the power of abstract reasoning. In the field of the affective life environment may be more potent than in the development of the intellect. But our means of measuring affective states and reactions are very imperfect, and any really scientific treatment of the relative influence of these two factors is as yet impossible. Where the influence of the environment can be measured with some crude approach to accuracy its limitations are becoming more apparent as knowledge advances.

ACTIVITIES OF THE CALIFORNIA WOODPECKER

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IN previous publications[1] I have dwelt in considerable detail on the surprising way (surprising as judged by commonly held notions about instinct and intelligence) these birds do things greatly to their advantage at times and quite the opposite of this at other times. For instance, I have shown that almost certainly their storing of acorns for food gives them a distinct advantage in several ways over other species of woodpecker that have not acquired a method of providing themselves with a food supply that is anything like as ample, as certain and as easily available as is this. The general adaptiveness of the activity is unmistakable.

What, then, can be said about their storing pebbles and other useless objects, which they do to a very considerable extent, except that this activity is not adaptive, or is maladaptive?

While on a woodpeckering expedition in June, this year, along what the local residents fondly call the "Bret Harte-Mark Twain Trail" of California's famous old mining region, I came upon several instances that well illustrate this contradictoriness. Two of these, one for each side of the balance sheet, I will now present briefly. Let us take the adaptive instance first.

About eight miles from Grass Valley on the road to Marysville is a relatively level area (the whole region is in the foothills of the Sierra Nevada Mountains) of perhaps four square miles, known as Mooney Flat. Scattered over this area and widely spaced are many old and very large valley oaks (*Q. lobata*). Live-oaks, probably the interior live-oak (*Q. Wislizenii*), and a sprinkling of blue oaks (*Q. Douglasii*) are also seen here and there. There are too a considerable number of digger pines (*P. Sabiniana*) and a few yellow pines (*P. ponderosa*). Around some of the farmhouses are a few large cottonwoods. To any one acquainted with the habits of the California woodpecker, this description of Mooney Flat is equivalent to saying that it is an ideal place for the species. As a matter of fact it contains a rather specially populous "settlement," as I have designated such localized and well-established groups of the birds.

The particular point to be made here concerns the nesting and residential holes more than the pits for acorn-storing.

I have previously called attention to the fact that these holes are almost but not quite always placed on the under sides of large, living branches of oaks, if, as is very common, oaks are used for this purpose. This location secures a large measure of protection against storms of rain, snow (in the mountains) and winds. Mooney Flat, like most such areas in California, is crossed in various directions by roads along which run electric wire lines and wire fences, the posts of which are of cedar, redwood or some other moderately soft wood. In such places the woodpeckers are inclined to transfer their

[1] *E.g.*, "The Nutritial Activities of the California Woodpecker (*Balanosphyra formicivora*)," *Quarterly Review of Biology*, 4: 455–483, December, 1929.

acorn-storing and home-making activities from trees to wire line poles and fence posts. Nowhere have I seen this transfer carried farther than on Mooney Flat. On one consecutive string of twenty-six poles, sixteen contained habitation holes, the number in each pole varying from one to twelve.

Now when trees are used for the holes the more or less horizontal position of the branches makes the placing of the holes for protection from storms quite easy. But what about such protection when the poles are used, these being typically straight up and down, and, of course, without branches? This natural query troubled me considerably for some time, and as a sort of answer I set up the counter question as to whether the birds really do use poles for nesting.

But this question was easily and conclusively answered. Pole holes are used, and in some localities are much used, for nests and other residential purposes. Does this mean that protection against storms is ignored in such cases? Quite accidentally at first I noticed here on Mooney Flat that several nest holes were on the north side of the poles which here were sawed with four flat equal faces. This fact noticed, and it being recalled that here, probably, as nearly everywhere in California, almost all the storms come from the south, systematic attention to the location of the holes easily settled the matter. Of a total of 131 holes in 35 poles, 92 were on the north faces and 7 on the south faces. There were 25 on west faces and 7 on east faces. This is not quite accurate, as it makes no allowance for the fact that the faces of the poles did not quite correspond in all cases with cardinal points of the compass. But since the observations were made at noon on a perfectly clear day so directions were easily determined, the small errors on this score could not materially affect the general result. It may be mentioned that the acorn-storing in these poles corresponded as to distribution pretty well with that of the nest holes; but with this we are not here concerned.

Here, then, seems to be a perfectly clear case of an action that is adaptive in a high degree. It is hardly open to doubt that the nesting and residential holes are better placed for the good of the birds, old and young, on the north than on the south sides of the poles. Furthermore, wire line poles have come into the environment of the birds so recently that their sharp differences from trees with respect to climatic conditions necessitated a very considerable change of action by the birds in order that security under the new conditions should be as great as under the old conditions. This problem the birds have successfully faced—*somehow*.

The subtle questions of exactly how the various environmental factors, the intense heat and light of summer sun and the storms of rain, snow and wind of winter have operated in the case we leave untouched for the present. Likewise do we leave untouched the still subtler questions of how the sensory, neuromuscular, glandular and other organic systems of the birds have operated. It is quite probable that experimental researches could be devised that would contribute to the answering of these questions. And efforts to this end are highly desirable since knowledge thus gained would tell us much about how the welfare of this species of woodpecker is secured in this particular situation through the working together of the various anatomical, physiological and environic elements involved. But such efforts are for the future and other zoologists than the present writer.

We now take up the single instance to be described of maladaptive action.

Having noticed along the highway power line poles that had been victimized by the woodpeckers to such an ex-

tent that they looked to be considerably damaged, while at Placerville I interviewed on the subject some of the "line men" of the Pacific Gas and Electric Company. One of these, Mr. Lombarde, proved to be genuinely interested in the performance of the birds and well informed on the matters I wanted to learn about.

He furnished ample proof that in some cases the poles are so extensively riddled, especially by the nest holes, that they have to be replaced. Blocks sawed from poles thus treated were shown me which showed that the nest cavity may be so large as to leave hardly more than a shell of wood. When this sort of thing happens to a pole of a high voltage line, there is nothing for it but to take the pole down and put up a new one—which may incur an expenditure of something like $200. However, my informant hastened to assure me that the company does not consider it has any real case against the birds—because the total damage done is so slight as compared with that coming from other sources, particularly from forest fires.

But the special point here concerns acorn-storing more than nest holes. Nearly all the larger poles used by the company are whole tree-trunks of the "Oregon pine" (really the Douglas fir, *Pseudotsuga taxifolia*), the trees selected being from eight to ten inches or a foot or more in diameter at base. The bark is, of course, all removed. Now what particularly interests us—and the woodpeckers—is the great way such poles have of cracking. The cracks may be many feet long and the largest of them may extend nearly to the center of the pole. Nor is any portion of the pole from bottom to top or any part of the circumference immune from them. These cracks are a great asset to the woodpeckers for their acorn-storing industry.

For several years I had been noticing that the nuts deep down in the cracks may be considerably flattened and in advanced stages of decay. Not until I was shown a pole by Mr. Lombarde that had recently been taken down had I been able to examine the contents of the cracks throughout the entire length of the poles, and to appreciate the full extent of this fate of the acorns. For quite naturally it is exhibited better in the upper part of the poles than near their bases, where alone I had heretofore been able to examine it. And my guide explained to me at once how the flattening and undoubtedly to a considerable extent the rotting of the nuts came to pass. The storing is, of course, done in the fall when the acorn crop is ripening. The acorns are then not only placed in the cracks but are pounded in—as is the birds' typical way of doing the business. Thus are the cracks which are wide open at this, the height of the dry season of the year, filled, often to the very surface of the pole, with the nuts.

Then comes the rainy season. Poles, cracks, acorns and all become thoroughly soaked. As a consequence the swelling wood tends to shut up the cracks—with the inevitable result to the stored acorns. Inevitable too are the consequences exhibited by the nuts when in the middle of the following dry season the cracks are again open, and the nuts are released from the vice-like pressure to which they have been subjected for months while thoroughly waterlogged.

Of the quart, more or less, of acorns extracted from two or three cracks of this pole, which I brought home as a sample, a majority remind one of pieces he might cut, or break, from the sole of an old dry shoe, the last wearing of which had subjected it to black, sticky dirt. I judge, but was not so informed, that this pole stood by the side of a road from which passing traffic raised much dust after the acorns were stored but be-

fore the winter rains came. And surely the acorns described are just about as available for woodpecker food as the comparable scraps of sole leather would be. A great majority of the acorns here stored for food are stored in such fashion as to make them quite useless to that end. The purpose for which the activity is performed is largely defeated by the way it is performed.

Now we might reason that the factors of contingency here involved—the weather and the expansiveness of wetted wood—reach into the future so far relative to the date of storing, and depend so much on physical principles, that even "wiser heads" than any zoologist ever supposed woodpeckers or any other avian species to possess might fail to foresee what would happen. The failure might be supposed due to insufficient experimental knowledge rather than to mere responsive or instinctive action. Possibly there is something in such reasoning. The known facts are not quite conclusive against it. But on the whole the evidence indicates that experience counts for little or nothing toward correcting the great liability of the woodpeckers to store the acorns in such a way as to sacrifice them largely or wholly as food. Much evidence to this effect I have presented in earlier publications. I merely mention—without details—a striking observation to this effect made on this same trip. A long-abandoned miner's house not far from Angels Camp was in full possession of the woodpeckers and was riddled with holes of the acorn-storing kind. The box-like window and door casing were particularly utilized in this way. The nuts put through the holes here drop into the inclosed spaces and are lost to the birds. Removal of the casing boards discovered great quantities—surely thousands—of acorns in these spaces. These nuts are a total loss to the birds. As for the poles, it is almost certain that the birds go right on putting acorns into cracks autumn after autumn only to be wetted, squeezed and rotted to uselessness the following winter.

After due allowance is made for the need of experience here as insurance against wasteful action, failure to profit by the knowledge, once it is had, must be accounted as maladaptive action.

It is quite worth recording, I think, that observations by farmers, line men and others whose residence and vocation bring the woodpecker much to their notice fix upon the birds these contradictory reputations.

Thus a road worker on Mooney Flat mentioned before any reference of mine to the selective placing of the nest holes that birds make their holes on the north sides of the poles as a protection against the winter storms. Without hesitation common knowledge dubs such action as "intelligent," "knowing," "brainy" and so on. Contrariwise, Mr. Lombarde, the line man, narrated to me that when one of his fellow-workmen expressed perplexity as to why the great amount of pecking and pounding done by the birds does not "jar their brains out" the reply of another workman was that they "do not seem to have any brains to jar out."

The only bit of philosophizing I venture at present in connection with such facts as those here recorded is this. The more I study the lives and actions of animals under natural conditions, the less am I inclined to think about and describe what I observe in such terms as instinct, intelligence, reason, thought and so forth, and the more do I think and speak about the phenomena in the terms of what the actions do or do not accomplish relative to the well-being of the creatures as individuals and as species.

It seems to me that much as we zoologists have made and must make of the concept of adaptation we have not made

nearly enough of it in its applicability to the *activities* of animals as contrasted with their *morphology*.

Such facts as that the California woodpecker can use its whole characteristic woodpecker mechanism to such strikingly different ends from what other species use theirs, without any recognizably corresponding morphological difference, seem to me more important for the interpretation of animal life generally, and human life particularly, than either our biology or psychology has recognized. And a fact that makes such studies as these significant far beyond the relatively simple cases themselves is exactly the simplicity of the phenomena. By this I mean that the creature's morphological characters and its activities are so easily observed, and are so close up, as one may say, to the vital needs which are the main goal of the actions, that there is little difficulty in bringing the entire group of phenomena into the picture at one time. For instance, it is almost impossible not to recognize both the purpose (speaking broadly) of acorn-storing by the California woodpecker, and the means by which this is done. Consequently relatively little thoughtful attention is requisite to enable one to see how much of success and how much of failure attend the activities, various of the obstacles they meet, how the birds utilize the stored materials, and so on. Very different as to details is this from the problem of observing the morphological characters of, say, a five-year-old child, correlating its actions with these, and assessing the actions on the basis of their promotion, or otherwise, of the child's well-being. Yet, unless we are all wrong in our modern theory of the nature and origin of man, the two cases can not differ down at the very bottom.

SCIENCE SERVICE RADIO TALKS

PRESENTED OVER THE COLUMBIA BROADCASTING SYSTEM

MEASURING THE EARTH'S ATTRACTION

By Dr. PAUL R. HEYL

PHYSICIST, U. S. BUREAU OF STANDARDS

A SAILOR is climbing the rigging of a ship. With one or both of his hands he is always firmly grasping a rope lest his foot should slip. A watcher on shore, with his hands in his pockets, feels a sense of security in that both his feet are firmly planted on solid ground. And yet what is his real situation? He is precariously hanging on by his feet to the outside of a great globe which is whirling rapidly in space.

Few persons ever stop to think of this. Some do not believe it. But one might be pardoned if, when the realization of that fact first dawns on him, he instinctively reaches out for something to catch hold of, and feels that after all the sailor may have been in rather the safer position.

The attraction of gravity is such a commonplace that we are for a large part of the time unconscious of it. Only when it becomes necessary to climb stairs or to lift trunks does it force itself upon our notice. It is, however, a matter for study and careful measurement on the part of scientific men, and measurements of the earth's gravitative pull are among those in which a high degree of precision is reached, something like one part in a million.

But why should any one go to the trouble of obtaining so precise a result? What is it good for?

It is one of the duties of the U. S. Coast and Geodetic Survey to map this great country of ours as accurately as possible. Now the surveying of large areas differs from small-scale work in that the curvature of the earth must be taken into account. It is not sufficient to assume that the surface is spherically curved, even on the Great Plains. One of the best ways of determining the change of curvature of the earth's surface is by the variation in the pull of gravity at different places. Where we are farther from the earth's center, the pull of gravity is less. But since such departures from spherical form are always very small compared to the size of the earth, we must be able to measure gravity very accurately indeed if the results are to be useful.

There is now in progress at the Bureau of Standards a measurement of the earth's gravitational attraction in connection with the map work of the Coast Survey. Determinations of gravity are made throughout the United States on a comparative or relative basis, with reference to a base station, where the value of gravity should be known to as high an accuracy as possible. While it is a comparatively simple matter to compare different values of gravity with one another it is quite another thing to determine the absolute value of gravity at the base station.

Now it happens that our Coast Survey has never had a real base station for gravity in this country. The measurements throughout the land have been compared, it is true, with the value of gravity at Washington, but the value at Washington traces its pedigree from the absolute gravity station at Potsdam in Germany. It is by no means as simple

a matter as it appears to extend comparisons of gravity across the ocean, and without a base station of our own we are not quite sure of our ground. The experiments now in progress at the Bureau of Standards are for the purpose of establishing such a base station in our own country.

Another use for gravity determinations is in prospecting for oil. The old method of drilling holes more or less at random (called "wild-catting") has become much too expensive. Wells are sometimes drilled very deep nowadays before striking oil, and the cost of a failure, or "dry well," may run into five figures. For this reason much attention is given at present to the use of physical methods of detecting underground deposits as a guide to favorable locations for drilling wells.

One of these methods depends upon the measurement of the force of gravity.

The pull of gravity may vary because of the nature of the material beneath the surface at different places. Perhaps there may be underground a large body of rather heavy rock, or again there may be a deposit of oil, very much lighter than the average crust of the earth, and consequently less attractive (from a gravitational point of view). Many an oil well has been discovered in this way; but it will be obvious that if the deposit is very deep it will require great precision in our gravity measurements to detect its presence.

How is the pull of the earth measured? There are several ways in which it can be done more or less roughly, such as by the use of a spring scale, or by measuring the speed attained by a falling body, but the most precise way is by means of a pendulum.

A pendulum swings because of the earth's attraction. Draw its bob to one side and release it; the earth tries to draw it vertically downward, but being rigidly connected to its point of support the only thing the bob can do is to move downward along a circular path. At the bottom of its swing, having acquired considerable momentum, it rises along another arc of a circle, gravity acting against it all the while, and eventually bringing it to rest. The cycle of motion is then repeated.

The time of swing of a pendulum is determined by two things: the force of gravity and the length of the pendulum. Consequently, if we measure the length of the pendulum and determine its time of swing we can calculate the value of gravity.

Both these measurements of length and time are capable of being carried out with a high degree of precision, and in consequence no other method of determining gravity can approach the accuracy of the pendulum. But to insure precision many precautions must be taken.

A pendulum suitable for gravity determinations is not at all like such pendulums as you may see in clocks, with a heavy bob and a rather light suspending rod. Such pendulums are far too flexible for purposes of accuracy. Gravity pendulums for absolute determinations are constructed so as to be as rigid as possible, usually of hollow tubing.

Much attention must be given to the mode of supporting the pendulum. In ordinary clocks and even in those used for astronomical purposes the suspension is usually a piece of flexible watch spring. But for gravity pendulums it is important to know the exact point of support, which is difficult to locate in a flexible strip. For this reason the pendulum used in precision measurements is usually supported by a smooth plane resting on a knife edge of agate or fused silica.

The expansion of the pendulum by rise of temperature may introduce error. To avoid this the experiments at

the Bureau of Standards are carried out in a room 35 feet below the ground, where the temperature changes very slightly from winter to summer. In addition, the material of the pendulum must be one which expands but little with rise of temperature. The best substance for this purpose is fused quartz. This, of course, makes a very brittle pendulum, but the greater accuracy attainable is worth the trouble and time involved in working with such fragile material.

In addition, the pendulum is swung inside a metal case from which the air has been exhausted. This permits the pendulum to swing for a long time, and also eliminates certain disturbing effects that would otherwise be caused by air currents or frictional resistance.

The length of the pendulum is measured by comparison with a standard bar (also of fused quartz) which has been compared with the standard meter bar which is by law the basis of our measurement system. The time of swing is determined by means of an astronomical clock whose rate is checked daily by the Naval Observatory time signals.

A rather curious feature of this experiment is yet to be mentioned. After the pendulum has been swung and measured with all the precautions that have been spoken of, it is turned upside down and swung again from another point of support. Were the pendulum perfectly uniform all along its length, this would not be necessary; but as such symmetry is never attainable, the pendulum must be swung in the reverse position also to eliminate these irregularities.

It may be readily understood that such a program of experiments may be expected to require considerable time. It is likely that the work will not be completed for several years, but when it is finished, the United States will be independent of any other nation in the matter of a base station for its survey work, and (we hope) the scientific world will be the richer because of a new determination of gravity of higher precision than has ever before been executed.

THE ANCESTRY OF OUR TREES

By EDWARD W. BERRY

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BERNARD—the finest flower of medieval monasticism (1090–1153) — said: "Trees and rocks will teach what thou canst not hear from a master," and it is of trees in rocks that I would tell you.

Some of us take great pride in our ancestry, and every one in these days when evolution is so much discussed has heard at least something of the ancestry of man and of the lower animals. Few, however, even among lovers of flowers and trees, have given much thought to the possibility of our favorite trees having had ancestors, or that the evolution of plants is quite as fascinating a field of study as is the field of animal evolution.

The stage setting is the same for plants as for animals only the time involved is somewhat longer. Plants are essentially the gatherers and storers of energy, while animals are essentially expenders of energy. Consequently animals must have plants for food. Hence plants were the first organisms.

The latest fraction of earth history, which we call the Tertiary period, comprises—according to recent studies of the atomic disintegration of uranium

and thorium minerals—something like 60,000,000 years. This period is commonly called the Age of Mammals, since it is during this time that the mammals or warm-blooded animals underwent their main evolution which culminated in the anthropoid apes and in man.

This same period may also properly be called the Age of Flowering Plants, since it also witnessed the main evolution of plants with flowers which produced seeds in closed seed vessels or fruits. The only difference in this respect between flowering plants and mammals is that the flowering plants started on their careers of world dominance some millions of years earlier than did the mammals, and there is a clear dependence of warm bloodedness on concentrated food which in the whole plant kingdom is produced almost wholly by the flowering plants.

Not only so but civilization itself was not possible until the invention of agriculture made possible the fixed abode and larger population denied to hunters and pastoral peoples. All our food plants are flowering plants, and this was not an accident but the inevitable result of their storage of concentrated foodstuffs in seeds or roots.

Toward the close of the Age of Reptiles, which preceded the Age of Mammals, we encounter the fossil remains of flowering plants in the rocks—petrified stems, casts of seeds, but chiefly the impressions of foliage, although in very fine-grained muds or fossil gums we may find preserved actual flowers. These early traces of the flowering plants are mostly of trees since trees stand a much better chance of being preserved in the sediments which formed the rocks before dissolution could overtake them. Among these early relics of long extinct forms we can recognize the ancestors of most of our familiar forest trees of the present.

Whether it be oak or chestnut, walnut or hickory, maple or ash, willow or poplar, sycamore or magnolia—all represent noble traces of an ancient lineage beside which the Cretan labyrinth, Ur and Nineveh are as but yesterday. Still living sequoias were young trees when Christ was born at Bethlehem in Judea; still living cypress sheltered Cortez on that night when the Aztecs almost succeeded in exterminating their conquerors. Still living sycamores were witnesses of De Soto's wandering in our Southern states.

Should we not then consider our trees as a part of our spiritual resources instead of purely an economic resource, and strive to get back a bit of that reverence of classic times when the forests were the abode of the gods?

The story of our tree ancestors is not only of their past distribution in time but also their distribution in space. Time and place then are the main themes, for we find that in the past they have been found in many countries where they no longer exist. For example, before the modern mountains were elevated in our West we find the remains of forests with magnolias and tulip trees, sassafras, gums, hickories and many others, which have since become extinct in that region and which survive in only eastern America and eastern Asia. Or in Europe before the glacial period wrought such havoc with its floras and faunas, we find many Asiatic and American trees—walnuts, hickories, magnolias, gums, sassafras, tulip trees, cypress and sequoia, and a host of others, since destroyed by the severe conditions of the ice ages, because their avenues of retreat were cut off by the Mediterranean and the transverse mountain chains of the Pyrenees, Alps, Carpathians and Caucasus.

We may trace briefly the history of a few familiar types.

The hickory, long considered to be a typical American tree, may well be taken to typify the spirit of the American pioneer, for its wood combines strength

and toughness to a degree unequaled among other trees. All the living species, except one recently discovered in China, are confined to southeastern North America. In those distant days when the primitive mammals had vanquished the last of the dinosaurs we find the fossil leaves of the hickory for the first time, and these oldest known records come from the western interior of North America. Somewhat later we find their remains in Europe and gradually their range was extended over the greater part of the Northern Hemisphere. The Ice Age exterminated them in Europe, and the elevation of mountain ranges which intercepted the moisture-bearing winds drove them out of western North America and most of Asia.

Our present trees are fine, slow-growing and long-lived trees—as many as 400 annual rings have been recorded; and undoubtedly if they had not become extinct in Europe before the advent of man they would have quite as many legendary qualities and poetic allusions as their relatives, the walnuts, or as the oaks.

The next tree that we will consider is the oak. The oak family, which includes the equally interesting chestnuts and beeches, took its origin from an extinct type which was abundant in the late Cretaceous and early Tertiary at a good many localities in the Northern Hemisphere.

The oak was Jove's own tree, according to Vergil, and it has always been an object of veneration and sentimental tradition. The Greeks supposed it to have been the first tree, and it was sacred to Zeus since it had sheltered his cradle on Mount Lycaeus. We read in the Old Testament that Jehovah appeared to Abraham beneath the oak tree at Mamre in Hebron, and in later times altars were built to the supposed Abraham's oak. Tree worship is hinted at in the story of Gideon, to whom the Lord appeared under an oak in Orphrah and told him he was to save Israel from the Midianites.

A great oak tree in Hesse dedicated to Jupiter was felled by order of Bonifacius and a chapel to St. Peter was built of its timber. The oak and mistletoe were part of the druidical cult in early Britain, and in more modern days it was believed that the spirit of the oak took refuge in the mistletoe during winter, when the trees were leafless. The old custom of bringing mistletoe into the house, so that the tree spirit might bring good luck to the household, is the origin of the modern use of mistletoe at Christmas time.

There are historic oaks in every region where large old trees are found—Charlemagne's oak near Paris; the Abbot's oak at Woburn, where Henry VIII hung the Abbot in 1537; the oak in the New Forest against which the arrow that killed William Rufus is said to have glanced; the Royal Oak at Boscobel in which Charles II hid after the battle of Worcester; the William Wallace Oak at Torwood; Alfred's Oak at Oxford; the Charter Oak at Hartford; the Wye Oak in Maryland, and many others.

The oak is especially esteemed by the Anglo-Saxon race not only as the monarch of the forest, which, turned into ships, would forever preserve English liberty—but more as a fit symbol of their character that might yield to adversity but which was not to be uprooted or changed by passing storms.

Not only did maritime folks appreciate oak planking, but the lowly keepers of the swine appreciated the bounty of the oak, in fact the Greek *choiros*—a pig, is in allusion to acorns; and tradition has it that acorns were the staple food of humanity before Demeter introduced grain on the earth.

In the Doomsday Book the forests are enumerated for taxation by the number of hogs they could fatten.

Although the oak may be the monarch of the forest in the temperate zone it is by no means confined to that region, but is well represented in most equatorial regions except Africa and South America. The West Indies have a number and there are over 300 varieties in Central America.

Although so abundant at present the oak line is ancient, and doubtless their leaves were eaten by herbivorous dinosaurs. The leaves of the more ancient species are with difficulty distinguished from those of the chestnut and the beech, and hundreds of fossil kinds have been described. They seem to have had a northern origin and are found in Greenland, Alaska, Iceland and Spitzbergen in Upper Cretaceous and early Tertiary times. In glacial times oaks have been found in cave deposits and river terraces, and there is a species associated with the bones of the ape-man in Java.

The sweet gum belongs to the same family as the witch-hazel, a family all the members of which have a curious disconnected present distribution indicative of an ancient lineage.

No part of the temperate zone can compare with southeastern North America in the brilliancy of autumnal colors. And a considerable part of this is due to the golden yellow to carmine and wine-red of the star-shaped leaves of the sweet gum. It is only in recent years that we have discovered the beauty of gum wood for interior use; it is now often called satin walnut.

The modern range is from southwestern New England to Florida and east Texas. It reappears in the uplands of Central America, and other varieties are found in Formosa, Japan and southern China and Asia Minor. Formerly the ancestors of the present trees had a continuous range, and the score of extinct species that have been found in the rocks largely bridge the present-day gaps in distribution and carry the ancestry back to the early Tertiary. The oldest of these gums come from Alaska, Greenland and Oregon. Somewhat later they appear in southern Europe and toward the close of the Tertiary at many localities in central and southern Europe, Asia and western North America.

Their characteristic fruits, often called gum balls, have been found fossil at a great many localities. The gum seems to have flourished in Europe right up to glacial times, when like the walnut and so many other tree species it was exterminated by the harsh climate.

What has been so briefly sketched for the hickory, gum and oak is true of most of our forest trees. We need not grow sentimental about "Woodman, spare that tree," but nevertheless fire and the lumberman have worked more havoc with the forests in a few hundred years than all the natural vicissitudes of time, and surely a more general appreciation of the wonders of the past history and present beauty of trees might well replace that attitude that regards our forests as so many potential board feet and we might remember that a tree is no longer a tree when it is lumber.

THE SUN

By Dr. C. G. ABBOT

SECRETARY, SMITHSONIAN INSTITUTION

IN the first chapter of Genesis we read: "And God made two great lights; the greater light to rule the day, and the lesser light to rule the night." The lesser moon inspires the poets; but the greater sun inspires all life.

Our earth circles about the sun once each year, at the immense distance of 93,000,000 miles. Sometimes we are asked: What set the earth going, and why doesn't it run down and stop like a boy's top? Well, I can't tell you what set the earth going, or how many thousand million years ago it was. But the reason it keeps going is just that there is nothing to stop it. A boy's top slows up and stops because of the friction of its pivot and the friction of the air. The earth rests on nothing, and goes through empty space; so there is no friction or resistance of any kind to slow it up. Yet it can not escape from its liege lord, the sun, because the attraction of gravitation acts like a slightly flexible bar of enormous strength to hold it to the sun like the spoke of a wheel. The spoke, to be sure, expands and contracts a little each year, for the earth is about 3,000,000 miles further from the sun in July than in January.

Immediately you begin, perhaps, to think I've made a slip of the tongue, and meant to say that the earth was further from its source of heat in January than in July. But no. For quite another reason we find it cold in winter. It is because the sun is not then overhead, but is far to the south. So its rays are spread much more feebly over the surface of the earth in winter, and can not warm us so much as when shining more directly down in summer.

While we talk of the sun's heat, let us take up another question sometimes asked. Why is it, says some one, that if the sun's rays keep the earth warm it grows colder and colder the higher we go in the air, though we are approaching the sun all the time? It is because the air is so transparent. It's like the window-pane that always stays cold because it absorbs so little heat from the sunbeam that passes through it. When one ascends a high mountain, or in an airplane, the cold air rushes about and chills him just as it does the radiator of his car. The upper air is cold because it is transparent and it cools whatever it blows upon. As for going nearer the sun when one ascends, what is a mile, or even five miles, compared to the 93,000,000 miles to go to reach the sun?

Perfectly tremendous quantities of energy are contained in sun rays. If we could use them completely to do mechanical work, every square yard shone on directly by sun rays would furnish over one horse-power. The state of Arizona might furnish sun-power equal to about twice as much as all the power of coal, oil and water now used in the United States if there were solar engines of only 10 per cent. efficiency all over Arizona to convert solar energy into work. Hitherto such solar engines have all been too costly to make and run, since other power is made so cheaply. Perhaps it will be otherwise a century hence, and then we may find the great manufactories in desert lands where there are fewest clouds.

What supplies the sun itself with such an enormous output of energy? Astronomers and physicists now think that the sun and all the stars are gradually consuming. I do not mean that they are burning up as coal is burned. When coal is burned it takes on oxygen, and the product in carbonic acid gas is nearly four times as heavy as the coal that is burned. Strange, isn't it, to think that what goes up the chimney weighs nearly four times as much as what is shoveled into the furnace? Nothing like this takes place in the sun. The temperature there is so tremendous that water would turn to steam, the steam into oxygen and hydrogen, and the atoms of oxygen and hydrogen largely into electrons and protons, and all this with explosive violence if any water at all could reach the sun.

All chemical compounds are thus

broken up in that fierce heat. We have nothing on earth so hot. Iron melted in a blast furnace would look like a black spot against the sun, and even the arc light would seem a dull red glow against such transcendent brilliance as the sun's surface. If, then, the sun is much too hot to burn, even on its surface, and perhaps ten thousand times hotter still at its center, what do we mean by that consuming that gives out its tremendous radiant energy? We mean nothing less than the annihilation of the solar substance. Take hydrogen for example. Its atom, so far as we know, consists of nothing but a separation of two units of electricity, one positive, one negative, kept apart by some tremendous energy of motion. We suppose that in the center of the sun, under prodigious pressure and exalted temperature, the two electricities may sometimes be forced together. When thus the atom ceases to exist, the energy that formerly forced its two units of electricity apart appears as radiation, and journeys outwards into space.

Things are built on a tremendous scale in the sun. It is 860,000 miles in diameter. This is about 100 times the diameter of the earth, and the sun weighs over 300,000 times as much. It is not solid like the earth, but gaseous altogether. Still the gases are so tremendously compressed that if we examined them we should be apt to call them liquids. The sun, indeed, averages 1.4 times as dense as water, whereas the air we breathe is only about 1/1000 as dense as water. But gases get denser the more they are compressed, and with solar gravitation, even at the sun's surface, of nearly 30 times its force on earth, the compression of the gases in the deeper solar layers is tremendous.

The telescope seems to show little on the sun as interesting as the mountains, craters and smooth plains that fill the landscape of the moon. But we have to remember the scale of things. A sunspot that occupies only a fiftieth of the diameter of the sun's face is yet big enough to enclose at the same time two whole earths and two whole moons without touching the sun-spot's edges. A little bright dot called a faculus, that seems inconspicuous on the sun, may be big enough to match the whole land surface of our globe. Thus, viewed in the light of our knowledge, the solar features take on their true proportions.

Not only does the sun keep the earth warm enough to live upon, but it is the original source of practically all our power. By the preservation of coal and oil the sun's share in the growth of the vegetation of ancient times is preserved to us. By the flow of streams his present activity in evaporating the water of the oceans is conserved for hydroelectric power.

The most fundamental chemical reaction in the world depends on the sun rays which promote the growth of plants. Within their leaf cells the carbonic acid of the air is combined with the water drawn in through the roots. The product is grape sugar. From this as the raw material the complex substances of plant life, the delicious juices of the fruits, the oils of the nuts and the cellulose of the woody fiber and the leaves of plants are all built up. Only in the rays of light does this wonderful first step in plant chemistry take place. No plant may grow without light. Without plants there would be no animals or human beings, since plants are the primary sources of their food. Thus the chemical reaction whereby light makes plant sugar is the most fundamentally essential one to all life upon the earth.

At the Smithsonian Institution we are making studies about this fascinating subject. We are growing plants out of jars of water containing suitable chemical plant foods. They stand in closed

chambers where sunlight can be imitated by electric lights. We control the color of the light and seek to know just how efficient the different colored rays are to produce plant growth. Thus, without sight of sun or feel of earth, our plants are grown under closely measured conditions. This will bring new knowledge of exactly what is necessary to make plants grow in natural surroundings. Perhaps improved varieties of useful plants may result from such studies.

Another very interesting experiment we are making relates to the bending of plant stems towards the light. A long dark box has within it a light at each end whose colors and brightness may be exactly controlled. A little oat seedling grows up out of a flask of watery nutrient in the middle of the box. If it bends towards either light, the brightness of that one is reduced by the observer until the plant grows straight up. Thereby we measure the relative efficiency of different colors to promote this plant bending called phototropism.

In other experiments we are trying to learn more about the secrets of solar plant-chemistry. Ordinary analysis of complex organic chemicals does not easily reach to make known the structure of their molecules. We are endeavoring to build up a spectroscopic method which will give a deeper insight into these complex structures, such as the green chlorophyl of the leaves, and the far more ponderous molecules associated with plant life. How complex they are may be partly appreciated when one notes that molecules of certain types of individual plant substances contain as many as 30,000 atoms. Compare that with hydrogen or with oxygen whose molecules each contain but two atoms.

The final thing I have time to mention to-day about the sun is that it controls our weather. Summer and winter, day and night succeed each other as the sun appears higher or lower above the horizon. The atmosphere circulates in immense whirls and spirals according to the warming and cooling which attend the march of the sun in the heavens. The winds blow and the rain falls entirely because the sun supplies the energy involved.

Within recent years the Smithsonian Institution has established several solar observatories on high mountains in distant desert lands. Here our observers measure patiently, day after day, the exact strength of the solar rays on which the world's weather depends. Changes are found, some regularly periodic, others apparently haphazard. We hope that when a longer series of these values has been accumulated, weather men will be able to puzzle out the intricate effects which the solar variation leads to. Then it may be that seasonal forecasts of reasonable accuracy will result, to the great advantage of industry.

WHAT THE NATIONAL PARKS MEAN TO THE AMERICAN PEOPLE

By Dr. RAY LYMAN WILBUR
SECRETARY OF THE INTERIOR

The United States is fortunate in possessing, in its matchless national parks and monuments, a system of outdoor museums which offer almost unlimited opportunities for enjoyment. I have been asked to talk especially about education in the national parks. The term sounds formidable, but as applied

to the national parks education is but one form of the enjoyment to be derived from a park visit. Our nation is still a young one, and like all young things is consumed with a curiosity as to the "why" of things. It is that spirit which has made us successful in the development of the resources of our country and in science and invention. So it is but natural that it must be carried into our recreation.

It is not enough for most of us to go to a national park, hurriedly view its highest mountain, greatest waterfall or immense canyon, and then go on to something else. Except for the almost professional "tripper," most of us want to know something about the mountain, whether it was once a volcano and if not what caused it. We want to know how the canyon came to be, and the cliff over which the falls tumble. So, for lack of a better word, we call the service which meets this demand for information educational.

Perhaps a few words about the principal characteristics of the major national parks would not be amiss here. Several of them are of volcanic origin. Best known of this class is the Yellowstone. This, the first national park to be created in this or any other country, has six great geyser fields, with thermal activity that can not be matched anywhere. It also has a canyon of unusual beauty, a great lake and interesting mountain scenery. It is said to be a dying volcanic region; that the geysers are the last gasps of the old volcanic forces. This may be so, but after viewing one spot in the park known as specimen ridge, one wonders if the age in which we live is not merely an interlude between two great volcanic periods. Specimen ridge is a 2,000-foot cliff where nature in some way cut through a great plateau. Imbedded in this cliff may be seen the remains of twelve fossil forests, one above the other. The scientific explanation is that the first forest was engulfed and buried under an irresistible flow of volcanic mud and ash. Then volcanism ceased and sufficient earth accumulated on top of the ash to support another forest. This later suffered the fate of the first forest. So for countless ages volcanic activity followed periods of quiescence during which forests thrived. Who knows but what Yellowstone's forests of to-day may be the thirteenth fossil forest of geology's to-morrow? Visitors to the region are particularly interested in the hot springs, and one of their frequent questions is, "What happens to the hot springs in winter; do they freeze up?" Others, when told of the plants of the Arctic zone to be found in the park, ask, "How did Arctic plants get to Yellowstone from the Arctic Circle?" Since asking such questions is one of the amusements of park visitors, answering them has become one of the important duties of the park forces.

Mount Rainier Park, in the State of Washington, is the result of two forces of nature, volcanism and glaciation. As we know it, the huge mountain is sheathed in ice, containing our largest single-peak glacier system. Seen from an airplane, the glacier looks like a giant white octopus, for from its summit twenty-eight named rivers of ice, and many smaller ones, pour slowly down its sides, reaching out into the great forests and delicate flower-fields below. Yet Rainier also was once a volcano, and even to-day sufficient steam comes from inside the earth to melt holes in the snow near the summit. The bed of beautiful blue Crater Lake in the park of that name is the crater of an ancient volcano.

Glacier National Park, adjoining Canada's Waterton Lakes Park at the international boundary, is, as its name signifies, partly the result of glaciation. Before glaciation, however, a great cataclysm occurred in the interior of the

earth, and the pressure under what is now Glacier Park became unbearable, so that the surface of the earth cracked and one side was thrust up and over on the earth.

Our newest national park is the Grand Teton, containing the lofty Grand Teton Mountain group. Unlike the volcanic mountains of nearby Yellowstone, this range is composed primarily of gneiss.

Rocky Mountain National Park contains a typical section of the Rockies. The Front Range, which carries the Continental Divide, is a gnarled and jagged rampart of snow-splashed granite which, although not the highest or most massive part of the Rockies, is for many reasons representative of the noblest part of these mountains.

Yosemite Park, in California, is a wonderful mountain area, containing part of the Sierra Nevada Range. Among its most striking features are its beautiful valleys, part the work of erosion and part of glaciation. Spectacular waterfalls dash over the great gray cliffs. The valleys here were first dug out by streams cutting their way through the solid granite. Then came the glaciers, digging deeper, scooping out and polishing. In this part also the educational force has many questions to answer. One most often asked in Yosemite Valley, when massive Half Dome, high on the rim, is first seen, is "What happened to the other half?" The searcher after information is told that it was split in two by the forces of glaciation and that the missing half is now among the boulders that are scattered down the Mercer River Canyon at its base.

Sequoia National Park, also in California, contains another outstanding portion of the High Sierra, including Mount Whitney, our highest mountain outside of Alaska. This park and its little neighbor, General Grant, were originally reserved because of their giant sequoia trees, thousands of years old and some approaching forty feet in diameter, which now grow only upon the western slope of the Sierra Nevada. The ranger or naturalist who tells the great age of these trees must be prepared to substantiate his statement. It is easy to do so where the sequoias are concerned. While the exact age of the living trees can not be given, it can be estimated by comparison with other trees which for some reason died, fell or were cut across. For every year the tree has lived there is an age ring, and many trees have been counted that bear over two thousand age rings, and some over three thousand. John Muir, our famous California naturalist, told of having counted four thousand rings on one.

That portion of our Southwest included in southern Utah and northern Arizona is a region of colorful canyons. Three of the most distinctive of these gorges have been set apart as national parks. The fame of the Grand Canyon is world-wide. Here the Colorado River, working hard through the ages, has cut a great gorge nearly a mile deep and varying in width, inside the park, from four to eighteen miles. Seen from the rims, the river looks like a tiny ribbon winding its way through the maze of towering cliffs, but on approach it is seen to be a mighty, turbulent river, still, as may be seen from the load of brown sediment it carries, cutting away the earth as it rages toward the sea.

Zion and Bryce Canyon National Parks, to the north of the Grand Canyon, are entirely different. Zion Canyon is about the size of Yosemite Valley and is said to resemble it in general conformation, but its great domes and spires are distinctive in their carving and glow with a richness of color that is unsurpassed. The gorgeous red of Utah's Vermilion Cliff is the prevailing

tint for two thirds the way up the canyon walls, with startling white above.

Bryce is really not a canyon, but a great horseshoe-shaped bowl extending down a thousand feet through pink and white sandstones. This great bowl or amphitheater is filled to the brim with myriads of fantastically carved figures.

One of our parks, the Mesa Verde in southwestern Colorado, contains a marvelous collection of prehistoric Indian cliff dwellings and pueblos, the ancestors of our modern apartment houses. The most picturesque of the great communal dwellings were built in huge caves, where they were protected to a great degree from the elements and where they were difficult of access by hostile tribes. Others appeared simply as great mounds of earth when first seen by white men, but when carefully excavated revealed ancient dwellings.

The only national park in the East so far is the Acadia, on Mount Desert Island, Maine. This is also unique in being the only one where the sea and mountains meet.

Three other national parks are in process of establishment in the East. One is the Great Smokies area, taking in the most distinctive portion of the southern Appalachians. Another is the Shenandoah, in the Blue Ridge Mountains of Virginia. This area is also replete with historical associations dating back to early colonial days. Mammoth Cave is the third of these park projects. Under authority of Congress all these parks will be established when certain designated areas have been donated to the United States for park purposes. Under congressional direction the Florida Everglades in the Cape Sable region have also been studied recently, to determine the suitability of the area for park purposes.

In addition to the main, distinguishing features of the parks already referred to, most of them have a very interesting plant and animal life. We are endeavoring to preserve these areas as nearly as possible in their natural condition, compatible with increasing human use.

The so-called educational work in the national parks consists in explaining to those interested, in popular form, the peculiar formations which are the distinctive features of the park, and telling which of her powerful tools nature used in forming them; and in giving information about other natural-history phases of the areas. This information is conveyed in three principal ways—through trips of varying duration conducted by ranger-naturalists; through lectures given by naturalists and visiting scientists at the hotels, lodges and camp-fires in the public camps, and through the museums, which are fast becoming important tourist centers.

The growth of this educational work during the decade since its experimental beginning in 1920 has been phenomenal, and is entirely due to the popular demand for the increased service of this kind. More and more the public is realizing that the parks are more valuable from an inspirational and esthetic standpoint than from that of material recreation. Both uses are desirable and necessary if the parks are to serve their owners, the American people, in the fullest degree.

COMMUNICATION AS A FACTOR IN HUMAN PROGRESS

By RALPH E. DANFORTH

HUMAN progress comprises both constant improvement in living conditions and steady improvement in man. Rapid increase in communication is speeding up both these processes. Communication is like a net thrown around the world drawing mankind together, thereby multiplying his power, for in union there is strength.

The solidarity of the *United* States is the secret of our present prosperity quite as much as our natural resources. The strength of this union over so vast a territory and operating through such lively channels of communication is increasing our power at an almost incredible rate. Another motto, "Knowledge is power," also proves its eternal truth now that knowledge is being communicated as never before to the people of the world.

Communication aids in the discovery of knowledge, speeds up its proper sifting and evaluation and then disseminates it throughout the land. People come to know the truth and the truth comes to make them free. Liberty which does not enlighten is no true liberty.

Communication greatly helps the process of enlightening man and hastens the dawn of genuine liberty both personal and universal. Communication by the many lightning-quick methods now in use speeds the circulation of money in ways which would be absolutely impossible under older modes of communication, and this increased circulation of money increases wealth and prosperity of the people.

With more wealth and happiness the wise can be wiser and fools be more foolish till their folly chokes them and the wise survive. Disseminating knowledge, wealth and power is a more humane way than warfare to kill off the unfit and fortify the intrinsically worth-while folk. Give a man money and power, in short, real success, and he will quickly show what mettle he is made of. Mr. Firestone has said that only a small proportion of men can stand prosperity,

If success goes to his head, by which we mean makes him conceited, he is too small a man; if it goes largely to his belly he is no true man. If prosperity elevates and refines him, increasing his efficiency, adding to his knowledge and making him more useful and more generous, he is then the typical American of whom his country is proud. This type of man, found in abundance in the United States, is making the world take notice and send commissions over to us to see how we got that way. We are communicating to the world, and the world communicates with us. Without efficient and lively communication among ourselves this would not be.

As communication increases in the future results will be commensurate. But communication does not do it all, for unless our race produced a lot of big men no amount of communication would make great statesmen and great business men out of them. For this reason some visiting commissions may find difficulty in reproducing our prosperity in their home lands. Their studies should help considerably in developing whatever capacity for prosperity they possess.

The thrilling thing about world-wide communication is the new form of competition it will introduce between man and man the whole world over—person-

ality pitted against personality throughout the circuit of this earth, compared, contrasted, tested in all ways as to intrinsic values of all parts of the man and all qualities. The physical, mental and moral values of all people will be tried out more searchingly than ever before. People in general will come to see clearly the real value, or lack of value, in certain characteristics which they never thought much about before. They will think seriously and often about many traits and characteristics, whereas before they had paid scant attention to even a few.

A bloodless warfare, though a serious one, will arise between individuals of both sexes and all ages the world over. It will be a friendly warfare, if you can conceive of such a thing, yet inexorable, and before it much that is trash in the human make-up will go down, while lasting worth will stand out in stronger light and beauty. Those who have it in them to develop many of the latter qualities will have cause to congratulate themselves, while those who possess them not will hardly know why they and theirs are disintegrating. Already the forces are at work; they always have been in communities of any size, but the advancement of communication and the increase of knowledge through the inventions, discoveries and diffusion of the results and benefits thereof have greatly increased the competition in human values. The next few years will increase it much more. Old-time warfares are bound to go down before it, but new warfares, less deadly to the worthy, more deadly to the worthless, will take their place.

Not only will individuals be contrasted with individuals but governments with governments, educational methods with other educational methods, social systems with social systems, laws, policies, religions, scientific achievements, hospitals and all other institutions with their kind in all parts of the world will be subjected to the closest scrutiny, compared and analyzed, weighed and evaluated. A flood of light will reach to the remotest abiding places of mankind, and this light of knowledge will be most healthful in its effects. Whether they will or no, nations will be drawn into a federation of universal communication, a united states of knowledge.

The thought of the common welfare will be thrust upon the most selfish peoples; the most benighted will be flooded with enlightenment, and those individuals or groups that find no responsive chords within their being can but shrivel or wilt in the sunlight of knowledge and human progress like plants that have no roots. Like violins without strings they can take no part in the symphony of man, the triumphal march of man's soul.

Rapid changes are going on all around us in response to the diffusion of new knowledge, new machines, new chemicals, new fruits and other foods, new flowers, new sources and more sources of power, new means of travel, transportation and conversation. All this we may include in the scope of communication. One might naturally think that all of us in the more progressive countries would respond more readily and quickly to the further advance of communication in the immediate future than the peoples in the out-of-the-way lands could possibly do. I fear we have in the most advanced lands many individuals who are excessively dull, criminal or obstinate who will not advance as rapidly as the more responsive savages in the now unenlightened corners and jungles. Many individual savages will fail to comprehend or receive the new light of progress, it is true, but we have such savages in fair abundance in our home lands and in our

greatest cities, and also scattered throughout our farming districts. Everywhere they are to be found as well as in the unexplored regions. Everywhere there will be many who will spring with alacrity to the call of real progress, real truth and well-being, with the larger happiness it entails.

All around the world we will read one another's writings. Better than that, we will talk freely and inexpensively with one another around the world. Better still, we will see one another as we converse. Best of all, we will travel universally and cheaply and meet and know one another thoroughly all around the world. No one doubts the rapid improvements in all these lines of communication now before us. Yet it is hard even for the most imaginative to realize all that it will mean to us or to others.

As I write these lines I am enjoying the sunshine and pure air on a high hill-top in Massachusetts. Other articles I have published in this same journal have been reviewed, at times, in publications from India, California and Siam to the islands of the Pacific. Will any who may read this article be led to think more in terms of human progress, and so help speed the progress of man?

In the struggles of culture with culture, science with science, religion with religion, mode of life with mode of life, region with region as a place for human habitation, those cultures, sciences, religions, modes of life or regions contributing most to real progress and improvement of man will be favored, the others will be neglected. Some hangers-on may linger in each neglected field awhile, but like hair on the face of a man who shaves they are doomed. Seek the culture, the religion, the mode of living which holds the strongest stimulus to improvement even toward the point of ultimate perfection and you will find that culture, religion or mode of living which will persist through the ages. The sequence "Learn to do well," "Seek that ye may excel," "Be ye therefore perfect" is the imperishable secret of human progress.

Some regions of this earth now considered unsafe to live in may become favored spots of abode. Victories over tropical diseases are leading to colonization in lands where abundant sunshine favors more rapid growth of timber and fruit and vegetation in general. Many tropical regions are so high in altitude that they are never too hot for health. Regions too hot and regions too cold and regions too changeable can not be held in high esteem in the future.

The advance in communication will favor the mating of the best with the best the world over. A world aristocracy of those who combine healthiest bodies with soundest judgment and clearest vision will increase, improve and refine itself, no longer permitting periodic dilutions with blood of mediocrity. With the help of communication and other factors the excellent of the earth will approximate perfection, the meanest and vilest will approach destruction.

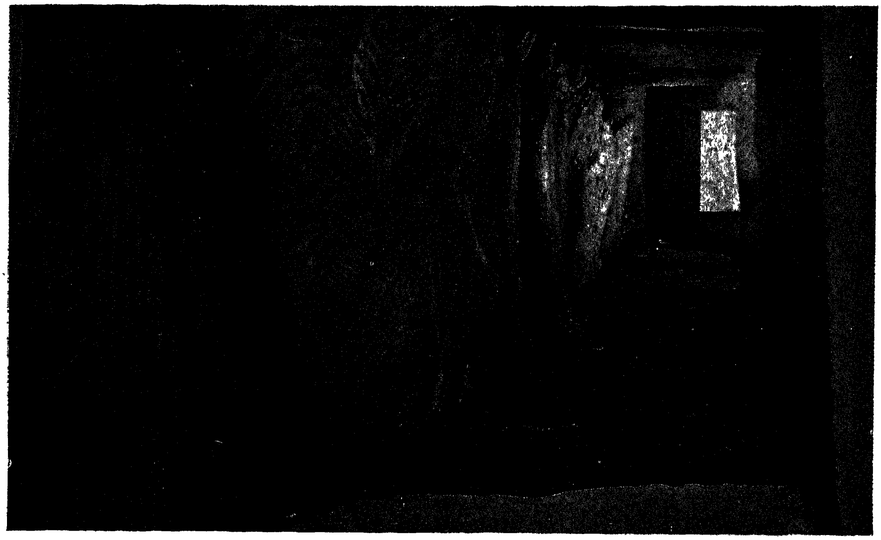
Communication will aid greatly the increase of joy in the world. Beauty will be cultivated and abound. Fragrance and sweetness will fill the earth. Man himself will become healthier and wiser. He will think ever in terms of human progress.

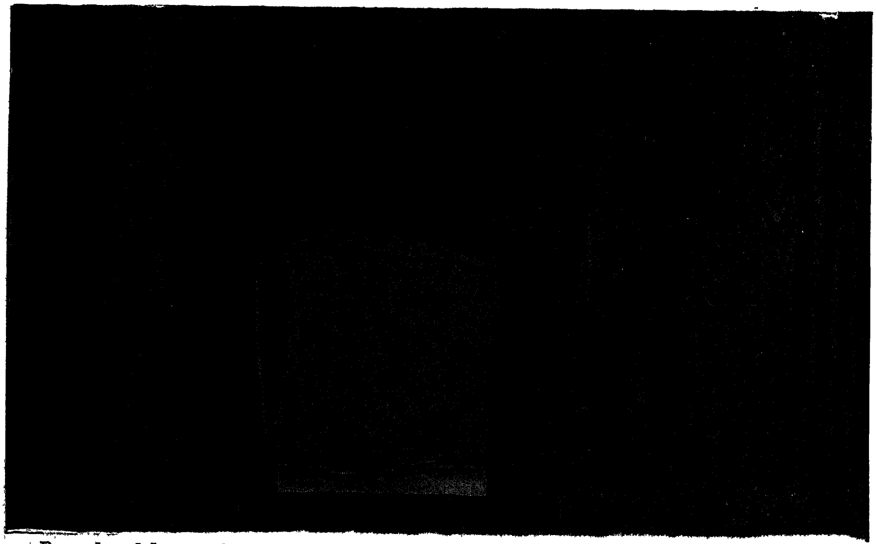
THE "FINGER-PRINT" CARVINGS OF STONE-AGE MEN IN BRITTANY

By Professor HAROLD CUMMINS
TULANE UNIVERSITY

A STORY partly told suggests diverse settings, and except to him who relates it all may seem equally fitting. Attempts to reconstruct the life and thought of prehistoric man are based necessarily upon uncompleted stories, which are revealed in remains of handiwork, sometimes so piecing together as to give consistence to the whole, yet often being quite fragmentary and tantalizing to the restorer. Occasional fantastic reconstructions of episodes in prehistory are inevitable. Carved on the stones of a Neolithic burial chamber in Brittany there are designs presenting a singular likeness to finger-prints, and these carvings may be said to constitute a passage in the unwritten history of men living several thousands of years ago. It is an obscure passage, for there are nearly as many interpretations as commentaries discussing it. One interpretation, backed by an impressive array of evidence showing that counterparts of the figures are to be found in actual finger-prints, holds that they are copies of these natural designs. The implications of the story thus rendered are far-reaching, having even a relation to the question of the origin of decorative design. If it be true that Neolithic men really noted the cutaneous patterns, and with the attention to minute detail which is claimed, credit is due them for a spontaneous interest and keenness in such observation hardly matched by average men of the present day. Accepting the finger-print source of the designs, the question naturally arises as to the purpose of the sculpturing. One "Doctor A.," writing in *La Chronique Médicale,* goes so far as to suggest that the designs are registries of the finger-prints of chieftains, recorded with precisely the object of modern finger-print files, that is, for the purpose of personal identification. These questions anticipate the issue, for the first concern should be the merit of the interpretation of the designs as finger-print motifs.

Neolithic men, in contrast to their Paleolithic forebears, engaged in building. Their success in handling immense stones evokes a deep respect for the engineering of the Stone Age. A stone weighing forty-four tons is thought to have been transported over a distance of nearly nineteen miles to the site of a dolmen at La Perotte. In the neighborhood of the structure which is ornamented with the "finger-print" carvings there lies a broken monument having a total length of over sixty-seven feet and an estimated weight of over three hundred and thirty tons, which is presumed to have been brought to the present site from a point five eighths of a mile distant, then lifted to a vertical position. Neolithic architecture has a definite association with the cult of the dead, many of the monuments, known as dolmens, serving as actual burial chambers. Dolmens are to be found in Europe, Asia and Africa; they number nearly five thousand in France alone. In Brittany there is one which has been described as the finest megalithic monument in the world, and it is this dolmen which bears the "finger-print" gravings. The dolmen is situated on a tiny island, L'Ile de Gavr'inis (Goat





—*Reproduced by courtesy of Professor H. F. Osborn and the Princeton University Press*

FIGS. 1 AND 2. INTERIOR OF THE GALLERY OF THE GAVR'INIS DOLMEN, SHOWING THE CARVINGS ON THE WALLS.

Island), in the Gulf of Morbihan, near Locmariaquer. It exemplifies a form of dolmenic construction termed the passage grave, allée couverte, characterized by the presence of an entrance gallery or vestibule leading to a widened compartment. The Gavr'inis dolmen has an entrance gallery forty-one feet long and about four and one half feet wide, the terminal chamber enlarging to a cubicle almost twice the width of the entering passage and having a height of nearly six feet. The walls are constructed of twenty-nine upright stones, and the whole is paved and roofed by slabs. The structure is imbedded, characteristically, within a low broad mound of earth, or tumulus. When the

dolmen was explored in 1832 it was found despoiled of movable contents. The impressive feature of the interior consists in the sculpturing of the walls with incised lines, fashioned into designs of great variety. It is worthy of note that the carvings are confined to the slabs of granite, two quartz uprights being unmarked. The cutting could have been accomplished with stone tools, though it is possible that implements of bronze were employed.

The photographs shown in Figs. 1 and 2 illustrate the general appearance of the sculpturings, as well as their size in relation to the dolmen. Fig. 3 contains several detail drawings of the designs. Concentric systems of horseshoe form, concentric subcircular figures, spirals, arching lines, sinuous lines, straight lines and other markings occur in various combinations.

Stockis, a distinguished authority on finger-prints, is the chief proponent of the interpretation which identifies the Gavr'inis carvings with the cutaneous patterns, holding that these natural designs served as models for the man-made designs on the stones. He points out that more or less exact counterparts of many features of the carved designs occur in the finger-prints of modern men. Not only are the patterns of the finger tips represented, but in two instances the portion of the palm near the wrist is reproduced. Stockis presents seventy-nine figures to substantiate this statement, illustrating actual prints in parallel with the carvings which they resemble. He directs notice, further, to the occurrence of interruptions, bifurcations and similar details of the sculptured lines, in support of the contention that the sculptures are faithful even to the degree of picturing the finest details of the single skin ridges. Continuing, he emphasizes that men of the Stone Age might readily have been attracted by finger-prints impressed in clay in the process of pottery making. The plasticity of clay favored the development of decorative art, and it has been suggested by Franchet and others that decorative carving was inspired by the designs of finger-prints in clay. Very simple designs were used in decorating the earliest pottery, imprinted with strings or bits of coarse-meshed textiles. Sometimes semilunar indentations were made with the finger-nails and the clay was pinched between the fingers in modeling. In the course of these manipulations the artisans may have become familiar with the finger-tip patterns. Apparently accidental impressions of the fingers occur on many specimens of ancient clay objects; it is said that Faulds, the pioneer English student of finger-prints, was led to this study through an interest stimulated by the observation of such prints in examples of prehistoric Japanese pottery. Finger impressions have been noted on old Roman vessels, on Assyrian bricks of the dynasty of Sargon, the adobe bricks of Mexican funeral mounds and in other primitive ceramics. But, to interpolate, these instances and their modern parallels only illustrate that the manufacture of clay objects is a possible medium for directing attention to the arabesques of the fingers, which might otherwise escape notice. The sign of the hand, whatever its signification, is regarded by Stockis as a possible source of meaning in the "finger-print" carvings, the patterns deriving a significance from their situation on the hand. The hand is thought to have had a religious or symbolic association, its representations being wide-spread in primitive art. One figure is known, indeed, in which rude designs are drawn within the outline of a hand, portraying in rough fashion the finger-tip patterns and "lines" of the palm. This example is one of a series of undated stone carvings, found in Nova

—*From Stockis, Anthropologie, vol. 31, 1921*

FIG. 3. A SERIES OF DETAIL DRAWINGS OF THE "FINGER-PRINT" CARVINGS ON THE UPRIGHT STONES OF THE DOLMEN.

Scotia, representing the open hand, joined hands, crossed fingers and the like.

Stockis, thoroughly convinced that the designs in the Gavr'inis dolmen are finger-print copies, believes that the interpretation applies likewise to similar carvings in the Irish dolmens of New Grange, Lough Crew and Douth, as well as on stones of the Island of Edey. Pointing out that the decorations of ceramics found in dolmens often take the form of concentric designs, he suggests that these and the familiar spiral decoration which has persisted throughout the ages may also have had their birth in the observation of skin patterns.

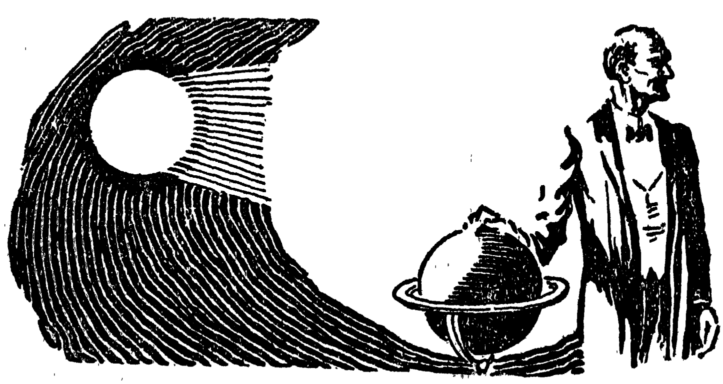
Before passing to other explanations of the Gavr'inis carvings it is well to review the varieties of designs which are found in the Breton dolmens other than those falling into the class resembling finger-prints. Closmadeuc arranges the carvings in a descriptive classification with seven divisions: a simple cavity hollowed in the rock (cupuliform sign); in the form of a curved rod (pediform sign); yoke-shaped (jugiform sign); comb-shaped (pectiniform sign); in the form of an ax-head (celtiform sign); shield-shaped (scutiform sign); in the form of an ax with handle (asciform sign). The meanings of some of the carvings are naturally obscure, though suggested explanations are not lacking. The sign of the chieftain's ax, for example, is definitely a reproduction of the ax which is known from actual examples. It is an abundant design at Carnac, and le Rouzic points to its frequency as an indication that to this burial place were brought the bodies of chiefs. The pediform sign has been interpreted as the representation of a stalk of grain. In describing a group of these figures carved on the stone of a Breton dolmen H. F. Osborn writes: "It shows four rows of single stalks of wheat—with a representation of the sun in the center —bowing their heads like the sheaves of wheat in the story of Joseph." The pediform sign has been compared also with the representation of the ax handle. It is not surprising that the much more elaborate sculptures of the Gavr'inis dolmen have received inconsistent interpretations. Both Osborn and le Rouzic associate these figures with the grain-stalk identity of the pediform sign, asserting that they are conventionalized symbols of the wheat field. Among other proposed interpretations it may be mentioned that the carvings have been explained as Druid symbols, as alphabetical signs, and some of the undulating lines have been thought of as symbols of a snake-worshiping cult. Another view regards the carvings as purely decorative effects, without attempting to trace their origin. Discussion of the relative merits of these views has no place in the present account, concerned as it is solely with an examination of the evidence relating to the finger-print interpretation.

The validity of the argument as to the opportunities afforded in pottery-making for display of the finger-prints must be granted. It is to be recognized also that many elements of the carvings are highly suggestive of finger-prints and that an importance may have been ascribed to their patterns by prehistoric men on account of the association with the hand. But the deduction of finger-print identity of the designs is open to question, for the resemblance may be merely a parallelism or convergence. Much has been written on the subject of designs in nature. It is not difficult to find fairly close replicas of the features of the cutaneous patterns in other natural objects, such as rippled water, rippled sand, the grain in woods and some rocks, erosion configurations,

bandings of color in animals, the shells of mollusks. Men of the Stone Age, like ourselves, were surrounded by countless designs in nature, and their range of observation would have been limited only by individual activities and interests. Conceding that all artificial designs, however combined or transmuted, must have their ultimate source in nature, it is still difficult if not impossible in many cases to trace the designs to their source. Certainly it appears unwise to express with positiveness any interpretation of the origin of the Gavr'inis figures.

Chance duplications of the cutaneous features are to be found in artificial designs, and a remarkable instance of this parallelism will be cited in illustration of the point that caution must be exercised in accepting the finger-print interpretation of the carvings. There appeared recently in the press, accompanying a verse by Edgar A. Guest, a cut which would attract the immediate attention of one who is interested in finger-prints. The illustration, reproduced here in Fig. 4, has a background of arching lines. The curvature of the system is such that it has the appearance of an actual finger-print from which the central area is cut away. The design, in fact, proves to fit exactly several finger-prints enlarged photographically to the same scale. Close inspection of the single lines shows, moreover, that they display certain of the features which are characteristic of skin ridges, forkings and reunions. Is the design a finger-print copy? The artist, Mr. Hubbell Reed McBride, has been very kind in supplying information with regard to the drawing, which makes it possible to use the figure as a modern test case of the argument of resemblance. The points of similarity to a finger-print are striking, yet it can not be maintained that the artist based the design upon finger-prints, for his own statement to the contrary is available. In the face of this instance it seems all the more unwise to make positive assertions respecting the quasi-finger-prints of the Gavr'inis dolmen.

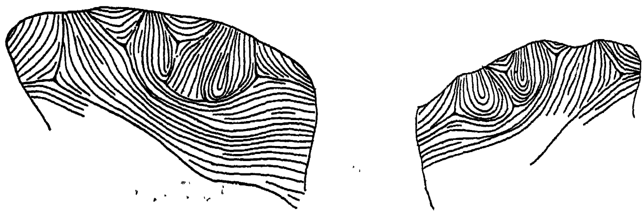
It will be recalled that Stockis lays much emphasis on the fidelity with which the men of Gavr'inis reproduced the details of the skin ridges with their forkings, interruptions, etc. These features in the carvings, however, may be simply adaptations to the curvatures of the incised lines and the interstices of the figures, rather than representations of the cutaneous details. Corre-



—Reproduced by courtesy of the artist, Mr. Hubbell Reed McBride, and the George Mathew Adams Service

FIG. 4. A RECENT ILLUSTRATION

CONTAINING A BACKGROUND WHICH CLOSELY RESEMBLES A FINGER-PRINT, YET WHICH WAS DRAWN WITH THE INTENTION MERELY TO SECURE "A GRAY TONE WITH A DECORATIVE EFFECT."

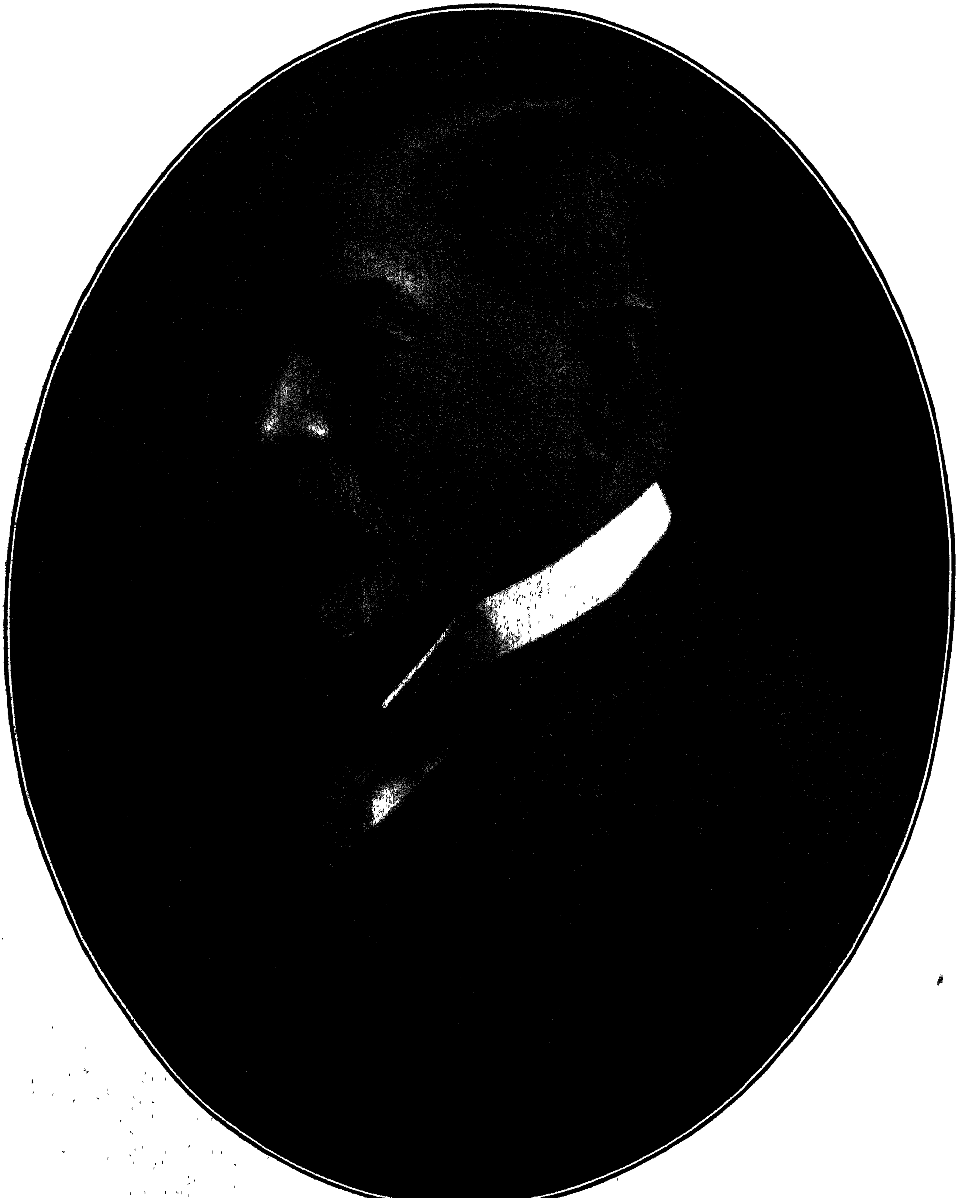


—*From I. W. Wilder, Journal of Morphology, 1930*

FIG. 5. TWO DRAWINGS OF PORTIONS OF PALMS WITH THEIR CUTANEOUS PATTERNS, ILLUSTRATING THAT FEATURES CORRESPONDING TO THE INTERRUPTIONS AND BRANCHINGS OF THE GAVR'INIS CARVINGS ARE INCIDENTAL TO THE FILLING IN OF IRREGULARLY CURVED SYSTEMS OF LINES.

sponding details appear in Mr. McBride's drawing. He writes that he frequently employs the line technique to secure "a gray tone with a decorative effect." In studying the drawing, as well as samples of the same technique in which the lines are straight rather than curved, it appears that the forkings are inserted in the effort to produce reasonably equidistant lines within an irregularly curved system. The sculptured designs shown in Fig. 3 exhibit numerous illustrations of a like adaptation of the details of the incised lines to the systems which they compose. If further evidence is needed to show the fortuitous nature of the branchings and related details there are many drawings in the literature relating to skin patterns (dermatoglyphics) which bear witness on the question. It may be explained that in morphological studies of the dermatoglyphics, unlike the application of prints in personal identification, the finer details of the single ridges are in general of minor importance. The investigator who makes a line drawing of the configurations of a palm, for example, needs only to trace a limited number of guide lines from the actual print; he then fills in the intervals with lines illustrating the forms of the patterns, in which reproduction of the ridge details is unnecessary. To fill in the patterns within the limits prescribed by the guide lines, with their highly variable curvatures, the frequent insertion of forkings and interruptions is inevitable. An example of this type of drawing is presented in Fig. 5. Stockis justly objects to an earlier expression of opinion that corresponding details of the Gavr'inis carvings are due to lack of skill on the part of the sculptors, insisting that they were carved intentionally. There is evidence of skilful use of the carving tools, hence the question narrows to whether intention was directed to the reproduction of details present in skin ridges or merely to the construction of continuously lined designs, which entailed the introduction of these filling details.

As a whole the Gavr'inis carvings give the impression of heterogeneity. Among the figures which may be likened to cutaneous patterns there occur many features which bear no resemblance to them. But is it not possible that all are inspired by a single primary motif, and that the apparently foreign designs are simply variations? However this may be, sound evidence that the carved designs had their origin in finger-prints appears to be wanting.



DR. FREDERICK ORPEN BOWER

EMERITUS PROFESSOR OF BOTANY AT THE UNIVERSITY OF GLASGOW, PRESIDENT OF THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

THE PROGRESS OF SCIENCE

THE BRISTOL MEETING OF THE BRITISH ASSOCIATION

WHEN the British Association meets in Bristol from September 3 to 10, it will do so for the fourth time in that city. At the first meeting there, in 1836, Lord Northampton, a vice-president, laid the foundation stone of Clifton Suspension Bridge. It is a tribute to applied science in one direction that the association has been intimately connected with the construction of two of the world's famous bridges, for after the meeting in South Africa in 1905 the then president, Sir George Darwin, opened the railway bridge over the Zambezi below Victoria Falls.

Bristol is an attractive center for a meeting of the association. Its own industries are varied; its site, and the country surrounding it, are full of geographical, geological, archeological and historical interests. It is necessary only to mention the close proximity of Bath, Gloucester, Cheltenham, Glastonbury and Wells, the Mendip Hills with the well-known Cheddar Caves, the Forest of Dean, and the gorge of the river Avon which still gives access to the port of Bristol for the smaller ships, though the bigger ships must now lie at the outports of Avonmouth and Portishead where the river joins the Bristol Channel.

All the sections of the association will be in full activity as usual. There are associations "for the advancement of science" in other countries, which have formed a much larger number of sections than the British Association, some meeting only to deal with special topics. The British Association permits its sections to form, if they want, special departments to do this—on the present occasion there will be in session a department of mathematics under the section of mathematical and physical sciences, and a department of forestry under the section of botany. But otherwise the sections range widely within their own divisions of science: in the Bristol program, for instance, we find the chemical section (to take a single example) announcing successive discussions on chemotherapy and the British dyestuffs industry.

In reviewing a British Association program, with its three hundred lectures, papers or discussions, there is a certain temptation to confine examples to those subjects of applied science which are intelligible to the layman and appropriate to the general interests of the day. Professor F. O. Bower, however, who will assume the presidency of the association in succession to Sir Thomas Holland, will deal in his adover the whole advancement of science, which he has made his own, namely, "Size and Form in Plants." Those presidents who in the past used to range over the whole advancement of science and in doing so occupy the rostrum far longer than the present generation would endure, sometimes in spite of that left an impression of sketchiness which their own erudition could not wholly remove. The presidential address to the British Association nevertheless maintains its place as the year's most important public pronouncement in science, and botany, which has not for some years been represented in the president, will now be so most properly and notably when Professor Bower details, as he only can for the understanding of the general audience who will hear him, the results of his own prolonged researches.

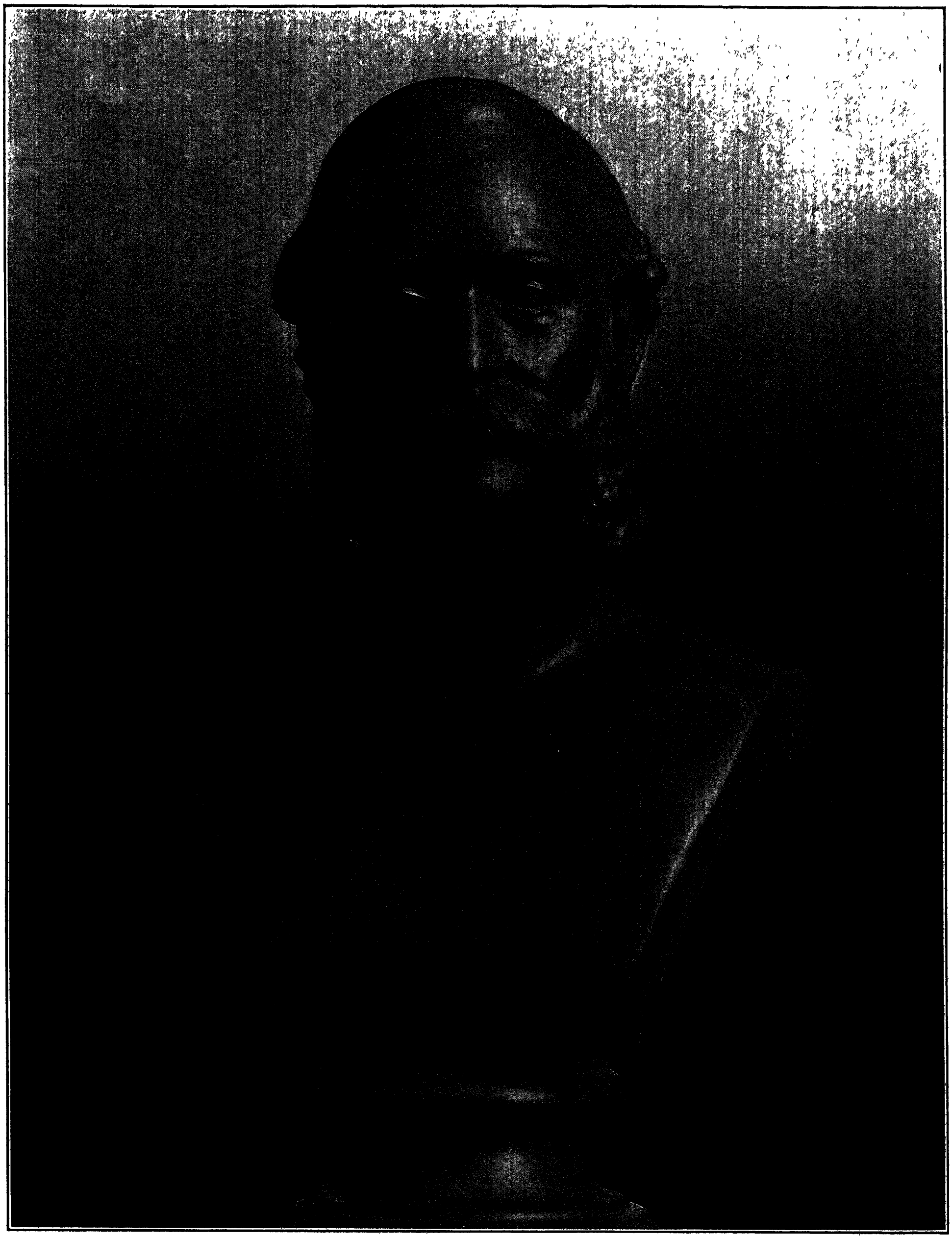
The sections of botany and zoology will both be impressed by their respective presidents, Dr. W. T. Calman,

of the British Museum of Natural History, and Dr. A. W. Hill, director of the Royal Botanic Gardens, Kew, in their addresses, with the importance of the taxonomic outlook in those subjects. The agricultural section will hear an address on veterinary science from a South African president, Dr. P. J. du Toit, to whom at the meeting in South Africa last year the section owed much for its success. The facts that the section, among other topics, will discuss fertilizers and that one of the evening discourses to the whole association will be given by Dr. R. E. Slade on "The Nitrogen Industry and our Food Supply," give rise to the recollection that it was at Bristol in 1898 that Sir William Crookes delivered his presidential address to the association which contained the classic prediction of a world-shortage of wheat unless agriculture should enlist the aid of chemistry. Geologists will find much field-work to interest them around Bristol. Their section will combine with those of geography and anthropology in a full discussion of the relations between past pluvial and glacial periods.

The anthropological section will discuss the important topic of a national folk-museum; and it will hear Miss Caton-Thompson on the investigation which, undertaken last year at the instance of the association, demonstrated to all save the incurable romanticists the medieval status of the ruins at Zimbabwe in Rhodesia. The educational section will receive an address from Lord Eustace Percy, a former president of the Board of Education, on "A Policy of Higher Education," and, following the customary arrangement of its program, will discuss groups of communications on outstanding current topics in education, such as the central schools. The section of economic science and statistics has as its president Professor T. E. Gregory, whose address will deal with "Rationalization and Technological Unemployment," and it is understood that leading representatives of the section will take part in an afternoon meeting arranged during the association's week by the management research groups. The geographical section will consider a topical subject in receiving certain communications on town-planning. A similar and not unrelated subject is that of national parks, which will be appropriately dealt with at a conference of delegates of corresponding societies, which are local scientific societies all over the country, whose interests and activities might well be used, and in some instances are used, in the direction of the preservation of rural beauty and scientific interest.

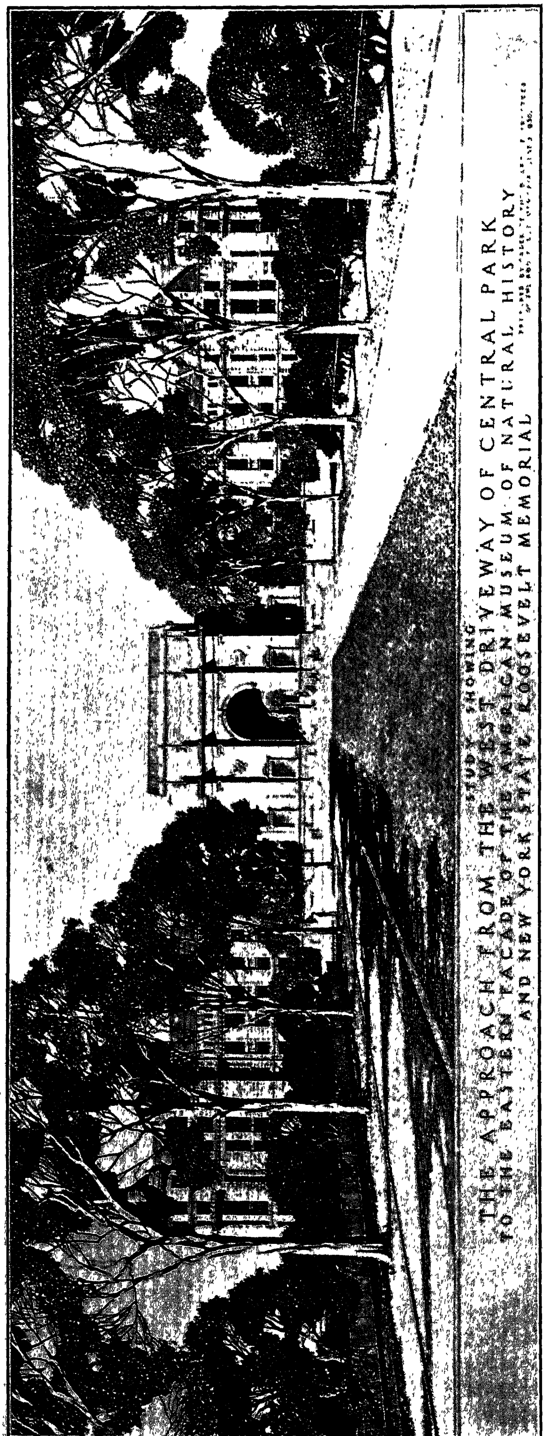
"Wireless" inevitably plays its part in the meeting: the British Broadcasting Corporation will stage an educational exhibit; Professor E. V. Appleton will give an evening discourse on "Wireless Echoes"; and the section of mathematical and physical sciences will discuss the meteorological relations of atmospherics. The section will have the advantage of meeting and witnessing demonstrations in one of the finest physics laboratories in the country, that of the University of Bristol (in which most of the association's work will be centered).

Public lectures—those, that is, to which the public and not only members of the association are admitted—have been asked for with unusual and gratifying freedom, not only in Bristol but also in neighboring towns. Among such lectures in Bristol, Sir Arthur Keith will speak on the debt which modern anthropology owes to a famous former citizen of Bristol—Dr. John Beddoe, and Sir Daniel Hall will interest the local fruit-farming industry concerning research on apples.



DR. WILLIAM T. G. MORTON

A BUST PRESENTED TO THE MASSACHUSETTS GENERAL HOSPITAL, BOSTON, BY THE ASSOCIATED ANESTHETISTS OF THE UNITED STATES AND CANADA. IT WAS DR. MORTON, A BOSTON DENTIST, WHO FIRST DEMONSTRATED PUBLICLY THE ANESTHESIA CAUSED BY SULPHURIC ETHER IN A SURGICAL OPERATION ON OCTOBER 16, 1846. THIS BUST, DESIGNED BY CLARK MILLS AND EXECUTED BY TIFFANY, SHOWS MORTON AS HE IS BELIEVED TO HAVE LOOKED IN 1846. THE BUST IN THE HALL OF FAME OF NEW YORK UNIVERSITY SHOWS MORTON IN THE UNIFORM OF A CAVALRY OFFICER IN THE CIVIL WAR NEARLY TWENTY YEARS LATER.



—*Courtesy of the American Museum of Natural History*

THE NEW YORK STATE ROOSEVELT MEMORIAL AND THE EASTERN FAÇADE OF THE AMERICAN MUSEUM OF NATURAL HISTORY FACING CENTRAL PARK

THE NEW YORK STATE ROOSEVELT MEMORIAL

THE splendid memorial to Theodore Roosevelt which is to form the central portion of the east façade of the American Museum of Natural History was first brought to public attention by the suggestions of the press in 1919. By December of that year a memorial to the great president had gained wide acceptance and met with the approval of Mayor Hylan and Governor Smith, as well as many leading citizens of New York.

At the time, Governor Smith advised Professor Osborn that it had become a matter for legislative action, and in 1920 the legislature passed "An Act creating a commission to investigate and report on the proposed memorials to Theodore Roosevelt, and making an appropriation therefor."

The work of the commission proceeded steadily, and in 1924 the legislature passed an act providing for the erection of the memorial in New York City "as a free public education building and made an appropriation for expenses." As now amended, the act provides that the memorial shall be erected at a cost to the state not to exceed $3,500,000.

In October, 1924, Governor Smith named the following trustees: Professor Henry Fairfield Osborn, chairman; Mr. Peter D. Kiernan, vice-chairman; Mrs. Douglas Robinson; Mrs. William H. Good; Mr. Chauncey J. Hamlin; Dr. Charles W. Flint and Mr. Sullivan W. Jones.

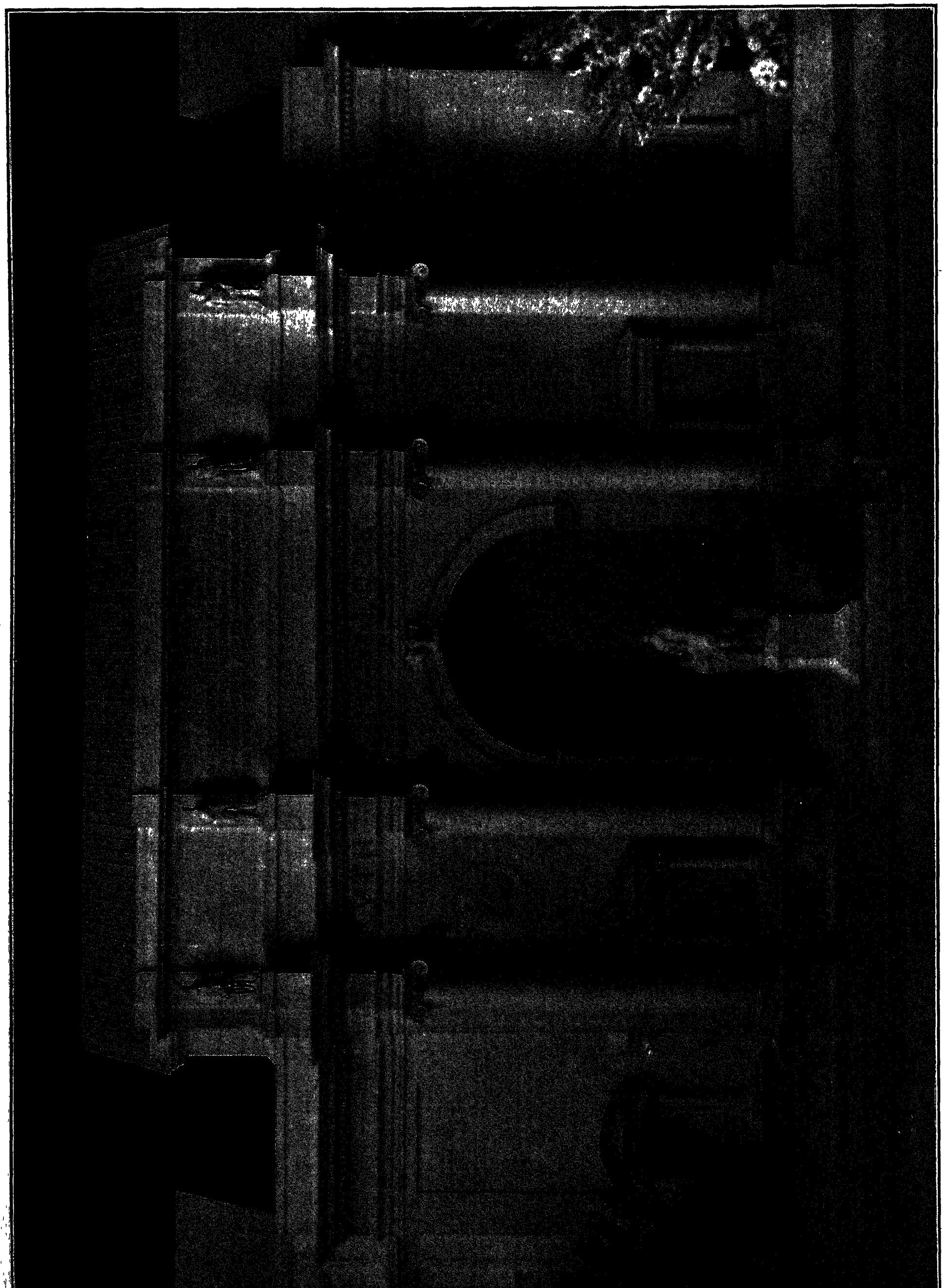
In 1925, the trustees invited a competition of the leading architects of the state, and the prize was awarded to John Russell Pope, of New York City. Mr. Pope entered on this work with enthusiasm, and on July 26, 1926, the plans and specifications were ready for the award of the first contract.

Since that time the trustees have carefully studied the requirements of public buildings in order to establish every convenience for the hosts of visitors who, it is hoped, will find in this memorial the inspiration to emulate those qualities of courage, honesty, dignity and humanity which were exemplified in the life of Theodore Roosevelt.

In planning the external features of the memorial, Mr. Pope turned to the stately architecture of the Roman Empire and found a suggestion for the façade in the triumphal arches of that brilliant civilization. This triumphal motive, with lofty arches reaching sixty feet above its base, flanked on either side by huge granite columns supporting heroic figures representing different phases of Roosevelt's life and crowned by a solid, simply inscribed parapet wall, not only symbolizes the great spirit of Theodore Roosevelt, but echoes the dignity of the state and the nation.

The paved granite terrace, fully 350 feet in length, flanked at both ends by huge pedestals carved in bas relief, supplies a fitting setting for the façade. This is reached by a short flight of steps from the sidewalk. Adjoining both ends of this terrace and encircling it to the rear, a vehicular driveway leads on a gentle slope to the first floor entrance. In the center of the terrace, immediately in front of the great arch, will arise a polished granite pedestal bearing an equestrian statue of Roosevelt with two accompanying figures on foot, one representing the American Indian and the other the primitive African. This heroic group will attain a height of thirty feet above the sidewalk, and, proceeding as in triumph from the lofty arch, will symbolize the fearless leader, the explorer, the benefactor and the educator. This group, it is hoped, will inspire the beholder with a sense of the all-pervading spirit of human adventure and benevolence.

On both sides of the steps leading to the entrance archway will be deep



—Courtesy of the American Museum of Natural History

FAÇADE OF THE ROOSEVELT MEMORIAL

—*Courtesy of the American Museum of Natural History*

ENTRANCE HALL OF THE ROOSEVELT MEMORIAL

niches displaying sculptured groups. Overhead there will be a richly coffered vault, while directly in front is a mammoth screen, a composition of bronze, glass and marble. This screen is to form the background of the great archway and provides a means of direct lighting to the interior, affording a comfortable vestibule to the building, at the same time conveying a true impression of the grandeur of the interior beyond.

The hall itself will be sixty-seven feet wide and 120 feet in length with additional recesses on both sides and at each end. Decorative panels will contain quotations from Roosevelt's writings and join the ensemble in paying tribute to his greatness. The floor will be richly patterned in marble mosaic design. The walls, to a height of nine feet, will be of marble, above which mellowed limestone will extend to an elaborately modeled Corinthian cornice, the whole to be culminated by an octagonal coffered barrel vault reaching one hundred feet above the floor. At either end of this vault the walls are penetrated by large circular headed windows which, together with the huge grilled opening at the main entrance, will furnish the hall with an abundance of daylight. It is the purpose of the architect that this

great room, planned to typify the out-of-doors, shall not want for brightness and cheer, and shall even admit the sunshine.

Great murals, however, are not best appreciated in such a direct light, wherefore the designer has skilfully placed them in the recessed walls at the three sides of the room. Guarding these recesses and supporting the vault overhead, are marble shafts, or columns, sixty feet high. The columns, crowned by ornate Corinthian capitals, and executed in deep, antique red marble, stand as sentinels to the distinction of the man, and lend a note of virility and strength so characteristic of Roosevelt.

To the right of the entrance will be placed the administrative offices and the trustees' room. On the left will be a group of rooms superbly finished in panelled wood, forming a suite reserved for the use of the Governor upon his official visits to the city.

On the axis of the great hall, monumental doorways with massive bronze doors will lead directly into a wide, encircling corridor. This corridor, while containing mementos and relics of Roosevelt, provides spacious connection with the present and future wings of the museum, to the stairways and elevators, to the class and educational rooms, and to the laboratories. The doorway opposite the main entrance connects also with the future Akeley Hall, a hall planned by the late Carl E. Akeley to retain for future generations a knowledge of the fast vanishing African life. During Mr. Roosevelt's lifetime, Mr. Akeley was his coworker and companion on many of his hunting expeditions. It is a most felicitous circumstance that this relationship should be perpetuated through this lasting association of mementos.

The southerly end of the memorial building will be joined by the new building containing splendid collections of Asiatic mammals, with an unexcelled series of fossil reptiles of ages long gone by, which never lose their fascination for the visitor. On the north, a hall will be erected which will house a collection of ocean birds and those inhabiting islands of all parts of the globe. Thus these structures devoted to natural science, with which Roosevelt's name is most closely identified, will fittingly surround the great structure raised in his memory.

GEORGE N. PINDAR,
Secretary

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THE WAYS OF MAN, APES AND FISHES

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THE ways of man are devious and perplexing. Why, then, add to our perplexities by dragging in the ways of apes and fishes? It is with the hope, at least, that a larger picture of life would give us some inkling of where man came from and where he is going. And besides, to visualize the coming and going of man, we needs must have other actors in the picture for measurement and comparison.

In the vast perspectives we have in mind, the minor deviations from the standards of behavior disappear and the great highways of animal life stand out with amazing clearness as supplementary explanations of one another. Mammals, birds, reptiles, fishes, sea-scorpions and many others are the great constellations of animal life. They are our fellow travelers along the Milky Way of the biological heavens, and it is only by their beacon lights and trailing orbits that we can plot the curve of man's ascent.

Too many lights confuse us and defeat their purpose. It is well for us, therefore, that our guiding stars are far apart and far away. But on the other hand, it inevitably follows that there are more missing links in our starry chains of evidence than real ones. That is, the unknowable blanks in all our plotted curves of evolution are much greater than the dot-like sparks of evidence which roughly, but surely, indicate the evolutionary course of events. The biologist bridges the minor gaps on the assumption that developmental changes, once initiated, tend to carry on in their predetermined directions. The major ones may call for supplementary interpretations that differ with different interpreters.

The widest gap, or the so-called "missing link" in the evolution of animal life, is not between man and the apes. Far from it. From man to his nearest apelike kindred and far beyond them down to the fishes, the main line of animal evolution is clearly indicated by a chain of evidence so closely linked that no zoologist is inclined to question it. But between the fishlike vertebrates and the invertebrates comes the widest and most perplexing gap in the whole animal kingdom. It separates the genetic tree of animal life into two great divisions, an upper and a lower, that stand on widely different levels of bodily organization. The events that bridged this great gap—joining high road to low road, or uniting the root, stem and flower of life into a continuous series of genetic developments—were no doubt of profound significance.

These two problems—the genetic relation of man to apes, and vertebrates to invertebrates—are to-day among the outstanding problems of animal evolution. In some respects they are much

alike. Both problems touch the foundations of all the biological sciences and have a direct bearing on the problems of every-day life.

The brilliant discoveries of the last generation or so have greatly changed the mental attitude of the biologist towards evolution and have raised many new problems to perplex him. But his main conclusion as to the reality of evolution and the origin of man remains as it was in Darwin's time. In plain language, biologists regard man as a special kind of ape, a very distinguished ape, to be sure, but nevertheless an ape and the offspring of apes whose ancestors, in the days of their prime, were some sort of primitive monkeys. And still farther back they were some sort of reptiles, amphibians, fishes and so on to still more primitive forms. As far as our vision reaches, this genetic sequence of forebears and offspring goes on for untold millions of years without any radical change in the method of producing them. It is not evolution, therefore, but the *method* of evolution which now chiefly concerns us. Evolution itself has long since passed out of the field of scientific controversy. There is no other subject on which scientific opinion is so completely unanimous. It is the one great truth we most surely know.

We shall try to show, very briefly, that this evolutionary method is a definite, irreversible process of creation, cosmic in extent, logical in all its causal sequences and with distinctly moral and ethical qualities of its own. It is righteous because, on the whole, it is creative, preparatory, self-sustaining and vital. All living and non-living things were apparently created in this logical or natural way, and all of them must act, or behave, in accordance with its moral and ethical principles. Under its compulsion, man has always tried, consciously or unconsciously, to imitate this fruitful process, and thereby has made his own vital profits. In this way arose within him a wavering image of realities, or a crudely corresponding system of logical activities, mental and bodily, which permeate and motivate all phases of his art, science and religion. And as man's vision of realities clarified, he was summoned to new endeavor and shown new ways to realize old ideals.

We have tried to illustrate in Figs. 1 and 2 the evolution of the principal kinds of human beings and other animals in a way that roughly indicates: (1) their rise and decline in geologic time; (2) the genetic relations of the great branches of animal life to one another, and (3) the relative amount of their upward progress. Some of the external characteristics of man and his nearer relatives are shown, rather than the less familiar anatomical structures on which they are based.

One of the chief factors that predetermines the bodily structure of any animal is the germinal material it has received as a heritage from its ancestors. Each natural group has a peculiar kind of germ-plasm of its own that gives continuity to the group and a recognizable similarity of structure to all its members. Thus the germ-plasm peculiar to all the great classes and orders has an extraordinary stability, or the power to reproduce itself, over and over again, for countless generations. These waves of reproductive power ultimately break on the shores of time and are visibly expressed in countless varieties of living forms, all under the bondage of their peculiar heritages (indicated in Fig. 1 by wave-like dotted lines).

But these genetic impulses can not be propagated in a vacuum. They live and grow in the fertile soil of their environmental opportunities. And as they grow, they create the more intimate environments of associated bodily parts and the wider environmental circles of associated individuals, all acting and re-

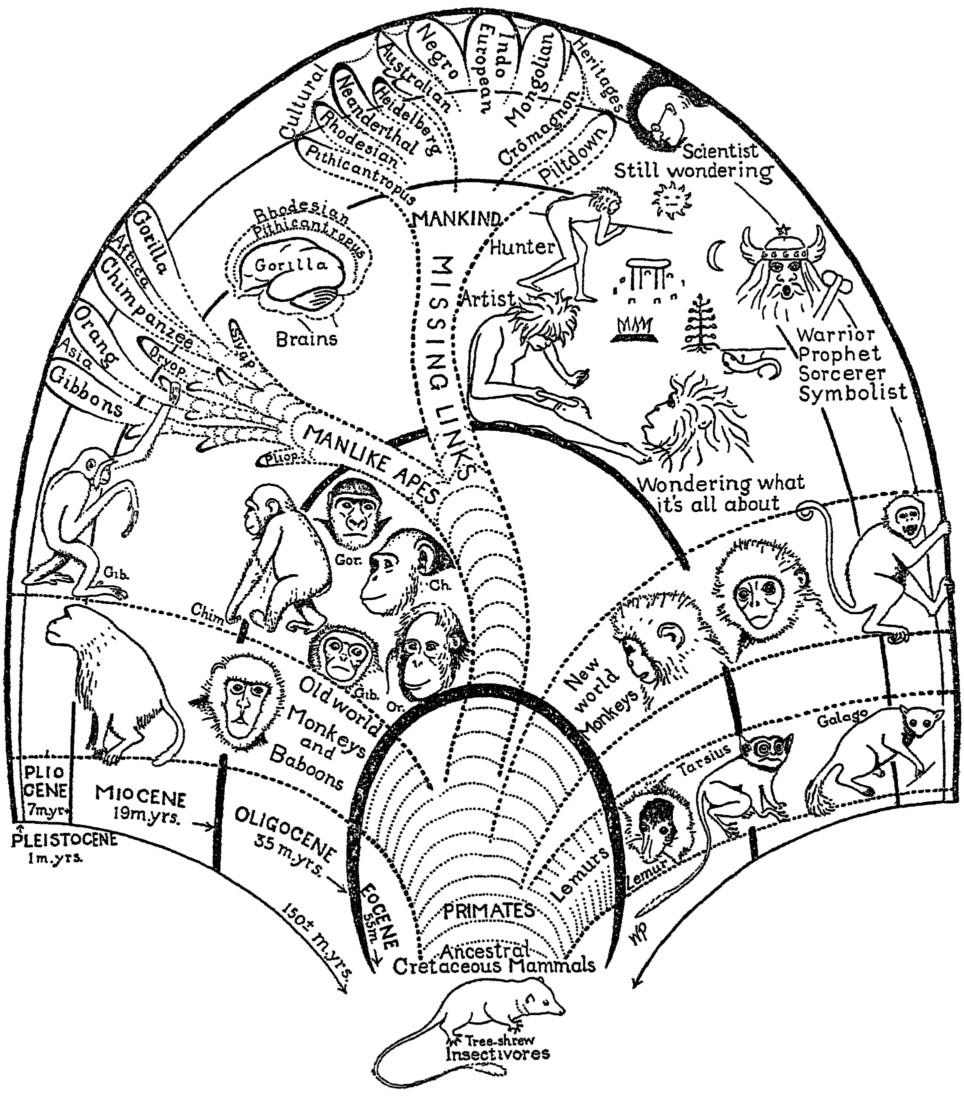

FIG. 1. A DIAGRAM TO ILLUSTRATE THE EVOLUTION OF MANKIND AND HIS NEARER RELATIVES. THE SYMBOLS OF THE GREAT CREATIVE PROCESS WHICH PLAYED SUCH AN IMPORTANT PART IN THE EVOLUTION OF MAN'S MENTAL IMAGERY, SUCH AS THE SUN, MOON, FIRE, WATER, MAGIC TREES, TOMBS AND DRAGONS, ARE ROUGHLY INDICATED.

acting on one another in the common business of growth and self-perpetuation. Thus the incidental opening or closing of a functional bodily door, a vocalized sex call, a germinating "idea" with its accompanying gestures, as well as the more obvious fluctuations of supply and demand, are cooperative causal factors in the evolution of life.

Laboratory experiments and measurements, however accurate or often repeated, are of comparatively little assistance in estimating the creative value of any one of these multitudinous factors. Our dominant faith to-day, as it always has been, is based on the perception of major results, *after* they have been produced in nature's laboratory.

Thus, to keep his head above the floods of watery details that threaten to engulf him, the biologist must apply the principles of birth control to his own activities. He will defeat his own purpose if, through lack of perspective, he fails to perceive the major products of nature and the trend of the great currents of evolution, for they constitute his most reliable standards of reference.

Candid self-inspection, from time to time, will also be helpful. Our present conclusion as to the origin of man has been reached only after a long series of cocksure assertions and more or less apologetic retractions. It is now based about as much on the reconsideration of old evidence, long since available, as on the impressiveness of the new. Our reformed mental attitude, as a requisite expiation for past sins, may be too obviously overdone. It is too often coupled with an ostentatious display of scientific precaution, and an undue exaggeration of petty details. On the other hand, the attempts to explain these details may fall far below the usual standards of scientific criticism.

This fickleness in judgment, individually and collectively, is about as characteristic of biologists as it is of other kinds of human beings, as the history of scientific opinion, especially in regard to the origin of man and the origin of vertebrates, so clearly demonstrates. In fact, the biologist, like all the rest of us, is at heart a hard-boiled fundamentalist and a dogmatic propagandist, as indeed he should be, if he has any convictions that are worth propagating. He is incredibly blind to the most obvious facts, if they do not fit into his peculiar philosophy. Then, perhaps, he may see a new light, and like the traditional unbeliever he is suddenly converted to a new dogma.

It now appears that man is far older, perhaps many millions of years older, than any biologist has dared to assume. What were these first men like? Where did they come from? How did they get that way? What a vast time-space theater for human development! How many causal factors for conjecture! How little we really know about them!

Shall we call the "first" man a dawn-man? That name, no doubt, is less irritating to the Biblical fundamentalist than ape-man, but it is not very significant to the biological fundamentalist. Every step in evolution is the dawn of a new day, and every man is a dawn-man to future generations. Of all open places on this earth, five, ten or twenty million years ago, was a plateau in central Asia the only campus available for the development of man? It may be. But we never felt very sure about the geographical location of the Garden of Eden, nor just what its ecological opportunities and restrictions were. Was the dawn-man a tree climber, a timid top-floor boarder in damp and gloomy forest chambers? The two-o'clock-in-the-morning dawn-man undoubtedly was. But how about the dawn-man that arose somewhat later in the morning? Was he a born hunter, driven by an overpowering "ambition" into the great open spaces of the sunlit, windswept uplands? Very likely. But what was his ambition, anyway? Was it the same ambition that drove the hunting worm to seek a better living in the fertile belly of a higher animal? Was the equally commendable ambition of the go-getter worm and the go-getter ape rewarded in the same way? As for climbing *versus* running, swimming or flying for a profession, we could hardly expect a hundred and fifty pound ape, or thereabouts, to make a worth-while living flitting from tree to tree like a monkey or a bee. The defects of his superiority would automatically restrict his freedom to the ground.

Such speculations, though justifiable as a crude outlining of possibilities, are

rather futile and should not be taken too seriously. The main fact remains that the deeper we delve into the geologic history of man the more kinds of human beings we find scattered here and there throughout the better known regions of Europe, Asia and Africa. And the older they are, the more they resemble, on the whole, the type of beings we call apes. There was, no doubt, a great variety of bodily and mental aptitudes among the many kinds of man-like apes and apelike men. What those minor details were, we do not know. But we do know that in the whole gamut of animal life there are no hands, feet, skulls and faces, no brains, no mental and bodily aptitudes, no records of embryonic and geologic developments, taken in the altogether, so much like our own as those of apes.

In all this there is nothing very startling or essentially new from an evolutionary standpoint. It is all in harmony with the Darwinian concept of the origin of man.

When we plot the course of animal evolution on a larger scale we find that all the genetic trails converge towards one great highway of life that takes us ever downward from man to primitive apes, and from there to monkeys, down to lemurs, and far beyond them to other arboreal mammals resembling the tree shrews. And then, over steeper terraces, the way descends to still lower levels, to reptilian, amphibian and fishlike prototypes.

There are no unaccountable embryological or anatomical gaps, nor any notable inconsistencies in the geologic records of this long genetic series as we trace it downward through many hundred million years. From mankind to fishes they are all vertebrate animals and all of them have the same elaborate sets of organs, arranged in the body in peculiar groups and subgroups in accordance with the same architectural plan.

When we study this enormous genetic series from man to fishes, the amazing fact is brought home to us that underneath the protean mask of countless adaptive adjustments and readjustments of bodily parts and organs to one another, the basic plan that makes them all alike never changes. It is evident, therefore, that during these hundreds of million years, all the combinations of germ-plasm in sexual reproduction, and all the variations in environments, could neither alter nor repress the fundamental potentialities of this structural plan.

There are no units of physical power by which we can measure or express those creative potentialities. And when we survey the actual unfolding of those potentialities, each upward step, as in a developing embryo, a preparation for the next; when we trace the perfectly logical series of adjustments that are made to meet the new demands of growth and to utilize its newly acquired freedom—all these cumulative results indicate a predetermined course of events, and something that is very much like a predetermined purpose. And that purpose can be rightly estimated only in terms of its own products.

Among the more notable improvements that raise the bodily powers to higher levels are the transformation of fins into legs, the substitution of lungs for gills, the addition of one chamber after another to the heart, various devices for sorting and distributing the blood and regulating the temperature of the body and innumerable inventions that better insure reproduction and make better provisions for the young and immature. In brief, they are just the sort of improvements in the give and take of vital traffic that must be made from time to time in a thriving city, if it is to go on living and growing.

The utility of such innovations is the measure of their creative value. As in

human history, such inventions, no matter how they are initiated, produce the great upward surges in the progress of life. They punctuate its history into eras and periods, and divide life into many different kinds of living things, each one on a different level of attainment, each one with different and unknowable potentialities.

Beyond the fish stage comes the widest gap in the whole animal kingdom. The differences between man and any other vertebrate are comparatively minor differences in a common structural plan. But the vertebrates and invertebrates seem to be built on fundamentally different plans. However, this difference is more apparent than real, as we have fully explained elsewhere.[1] Recent discoveries concerning the very ancient Ostracoderms, some of them as yet unpublished, in many ways confirm that explanation.

For a century or more, this subject has been a storm center of controversy among zoologists. It has been one of those strange battlefields where many issues were involved and where many gallant partisans of one view or another were firmly entrenched in old traditions. They attacked and counterattacked with dogmatic fury, but rarely with any notable effect. Meantime they calmly ignored one another. Here the innate fundamentalism of the scientific anthropoid was shown at its best and its worst. This is not a lament nor a claim for immunity. It is an explanatory field note on the ways of mice and men by a participant in the controversy for more than forty years.

Typical vertebrates make their first appearance in the Devonian age as highly developed fishes that are essentially the same as those alive to-day. But it is evident that they really did come into existence at a very much earlier period.

[1] William Patten, "The Evolution of the Vertebrates and their Kin," P. Blakiston, 1912.

With them are found the fossil remains of many other kinds of animals of very great antiquity. Two kinds are of special interest in this connection. One of them is a sort of "dawn-fish," if you please, called Ostracoderms. They once formed a great class of animals, and until recent years very little was known about them. The other kind are the giant sea-scorpions which for many millions of years had been the most active and highly organized invertebrates of their time. The sea-scorpions, although themselves long since extinct, have left many collateral descendants that are alive to-day, such as the little land scorpions, spiders and the so-called horseshoe crab, or Limulus. They constitute a special group of Arthropods called Arachnids.

Now we find, underneath a mask of confusing superficial details, that the basic structural plan of the Arachnids is the same as that of fishes, reptiles, apes and man. Furthermore, nothing like it is found anywhere else in the whole animal kingdom.

This structural plan, omitting technicalities, is a very intricate picture puzzle, or anatomical pattern, made up of nerves, sense organs, jaws, gills, heart, brain, endocranium, notochord and alimentary organs, so as to form definite groups of organs and bodily regions, each group consisting of a definite number of similar parts and functions, and all arranged in a definite sequence (see Fig. 3).

The agreement in so many fundamental peculiarities between the picture puzzle patterns of sea-scorpions and fishes is so complete that it practically excludes the possibility of a meaningless coincidence. Its significance is obvious. The conclusion is forced upon us that the main ancestral line of man extends far beyond the fishes, through the Ostracoderms, the sea-scorpions and their arthropod ancestors. And from these

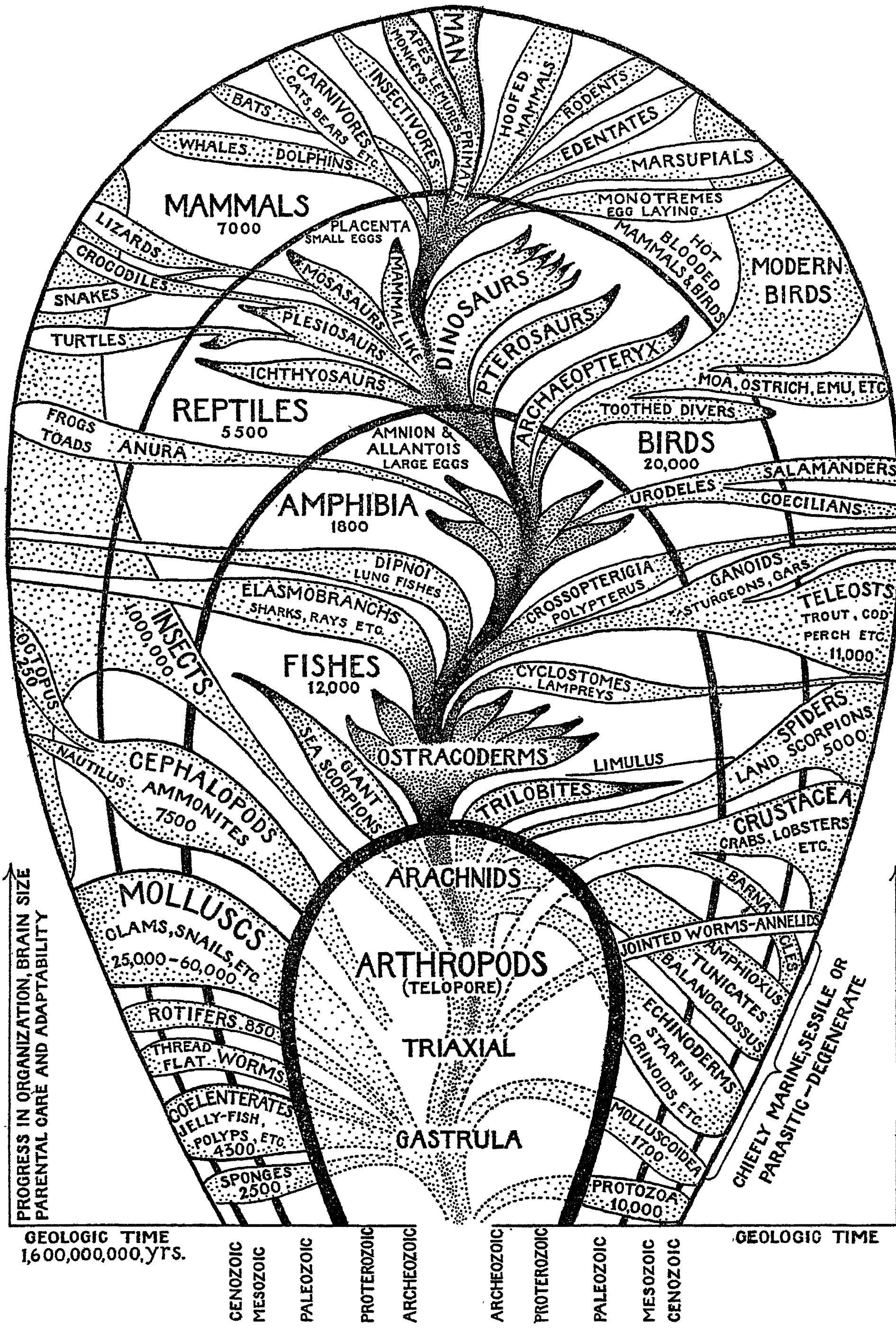

FIG. 2. A DIAGRAM TO ILLUSTRATE THE RISE AND DECLINE OF ALL THE GREAT CLASSES OF ANIMAL LIFE. EACH ANCESTRAL CLASS WAS ONCE A LEADING TYPE, THE APEX, HEAD AND FRONT OF THE SOCIAL LIFE OF ITS TIME. MAN CAME ON HIS METEORIC CAREER TRAILING CLOUDS OF RADIANT LIFE WHICH ENVELOPED AND SUSTAINED HIM ON HIS WAY.

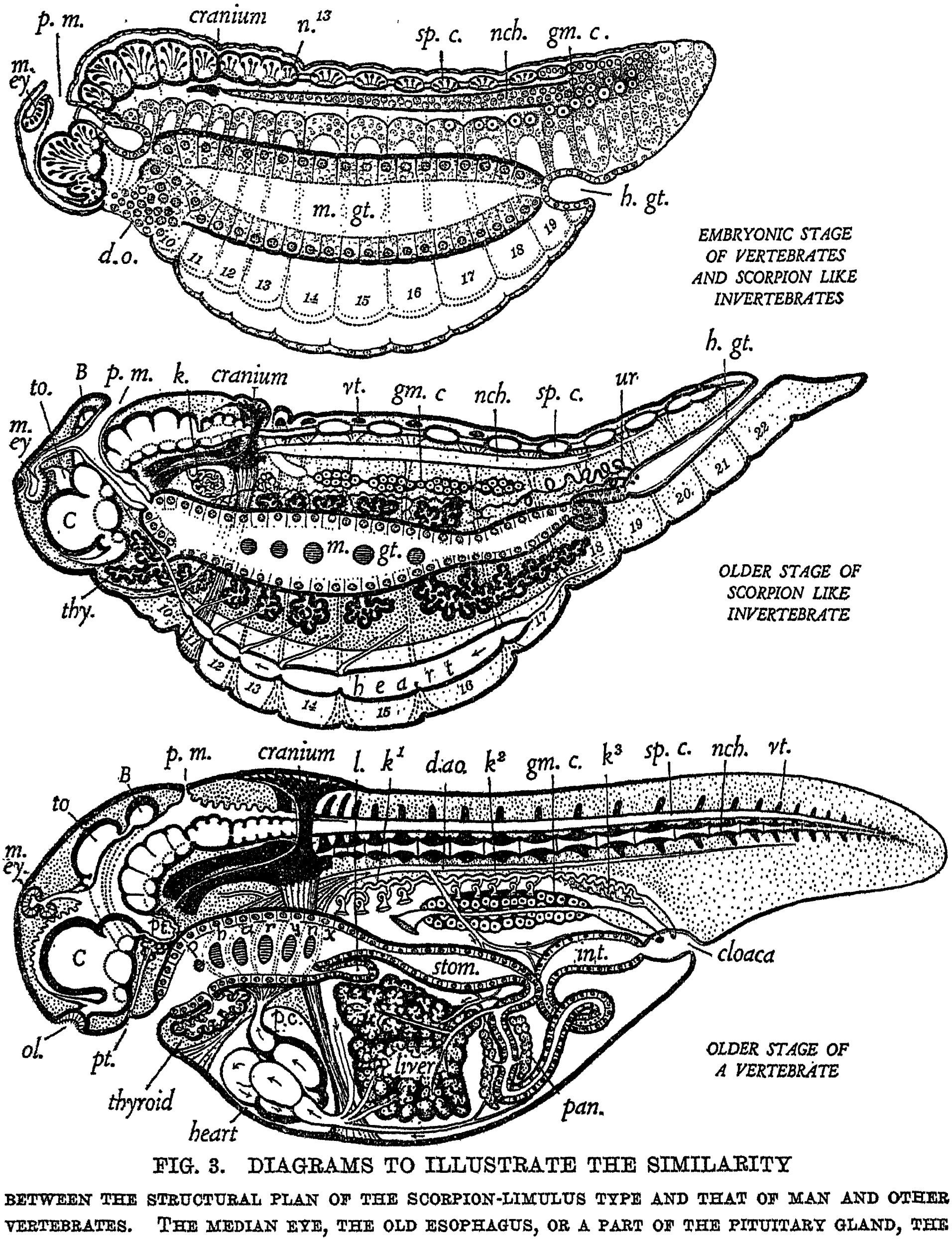

FIG. 3. DIAGRAMS TO ILLUSTRATE THE SIMILARITY BETWEEN THE STRUCTURAL PLAN OF THE SCORPION-LIMULUS TYPE AND THAT OF MAN AND OTHER VERTEBRATES. THE MEDIAN EYE, THE OLD ESOPHAGUS, OR A PART OF THE PITUITARY GLAND, THE ENDOCRANIUM AND THE GREAT SUBDIVISIONS OF THE BRAIN ARE AMONG THE MORE PERMANENT FEATURES COMMON TO BOTH TYPES. THE CHIEF DIFFERENCES ARE DUE (1) TO THE CLOSING OF THE OLD INVERTEBRATE MOUTH LEADING THROUGH THE FLOOR OF THE BRAIN AND THE OPENING OF A NEW ENTRANCE TO THE ALIMENTARY CANAL ON THE OPPOSITE SIDE OF THE HEAD; (2) TO THE OPENING OF THE GILL CHAMBERS INTO THE THROAT OR PHARYNX. THESE OPEN AND SHUT ADJUSTMENTS AND MANY OTHERS THAT NECESSARILY FOLLOWED IN THEIR WAKE WERE THE MOST DRAMATIC AND FRUITFUL INNOVATIONS IN THE WHOLE HISTORY OF ORGANIC EVOLUTION. THEY LIBERATED THE POTENTIALITIES OF THIS STRUCTURAL PLAN AND PRODUCED THE GREAT UPWARD SURGE WHICH IN HISTORIC PERSPECTIVE APPARENTLY SEPARATES THE FISHLIKE ANCESTORS OF MAN FROM THEIR ARACHNID-LIKE PREDECESSORS.

the way is fairly clear to the jellyfish and the protozoa (see Fig. 2).

It will be seen that each of these ancestral classes was once a leading type, the apex, head and front of the advancing social life of its time. Thus man came on his meteoric career, trailing clouds of radiant life which enveloped and sustained him on his way.

This larger and clearer perspective of the evolution of man, covering something like a thousand million years, in all sorts of physical and social environments, is of profound significance, not because sea-scorpions are more respectable ancestors than the mud-worms worshiped by the biologists of a generation ago, but because, knowing so much more of the orbit of man's ascent, we may better understand the laws that governed his progress. There is no other series of causal phenomena of equal extent that is so precisely predetermined in its inception, in the course it follows and in the creative fertility of its results. There is no other great series of phenomena known to science where the moral and ethical principles of evolution are so apparent in the performance, and where their application to human affairs is so obvious.

The four outstanding betterments in this upward progress of animal life were as follows.

(1) The upbuilding of bodily powers in each individual on its initial foundations. These processes are all of the same character and all move toward the same objective. That is, they are various economic betterments in the give and take of vital metabolism which serve to enlarge the scope of life. For example, the increase or decrease of local bodily production; the opening of more direct lines of communication, or the enlargement of transporting channels for the exchange of vital commodities to meet the new demands of bodily growth. In short, any betterment in the mutual service of the bodily parts and organs which better insures the welfare of the body as a whole and gives further vent to its latent potentialities.

(2) Heredity and parental provision. This includes all those betterments in the duplex machinery of sex whereby the accumulating profits, or heritages of life, are redistributed, renovated and conserved. It also includes all those betterments in parental shelters, in parental foraging and guidance, whereby maturity gives itself up to immaturity. Here the universal altruism of life, the secret preparation for anticipated emergencies and the sacrificial usage of all the highest faculties of life for the tender germs of life are most apparent.

(3) Social betterments. This includes all those betterments in the give and take of social commodities, or the destructive usage of one another's powers for recreative purposes. All such betterments tend to strengthen the functional bonds that unify and sustain the social life of plants and animals the world over. They tend to conserve rather than utterly destroy the more useful types of individual life. Here the real purpose of death, or the destructive side of life, is most apparent.

(4) Brains and mentality. All these bodily betterments depend on the cooperative nervous unity of bodily parts and organs with one another and with the activities of the external world. They are all registered in some way in the texture of the central nervous system. Hence the increasing volume and complexity of the brain is the clearest index we have of all these evolutionary betterments in nature's art of living and dying. It is the one visible agency that coordinates all phases of internal life and responsively adjusts them to the activities of the outer world.

Thus animal life advances on a very broad front, where the smallest particle, organ, individual or social group may be

a leading creative factor. The most striking advances are in bodily powers, in germinal, parental and social provisions for posterity, and in the relative volume of the brain.

As we have indicated elsewhere,[2] there is an unchanging method in all these cosmic and organic adjustments that has a distinctly moral and ethical quality. That is, over all the phases of growth and evolution there is a compelling directive discipline with ample freedom for profitable individual variation; an overpowering predetermination in the "nature of things," but with many fertile opportunities for adaptive readjustments, or for getting in right again with the new conditions created by growth and evolution. This process of adaptation, or this getting into more fruitful relations with the world at large, is the biologist's name for righteousness.

In the unavoidably mongrel metaphor of mechanism and vitalism, matter and spirit, nature virtually says to every individual thing, dead or alive: Thou shalt. Thou shalt not. Thou mayst. Be mutually serviceable or be destroyed. Sacrifice lesser values by rightly using them to make greater and more enduring values. Self-sacrifice by the right usage of individual powers for the common welfare is the source of all those enduring profits, or heritages, on which evolution depends. Evolution, therefore, is the cosmic yardstick of all these basic moral and ethical virtues, and the only authentic revelation of their creative values.

Good and evil are inseparable factors in this method of creation. They are but other names: (1) for the various processes of destruction, reconstruction and innovation in cosmic and organic metabolism; and (2) for all those maladjustments produced by growth of any particular kind, and the adaptive readjustments that are requisite for existence under the new conditions so produced. All these factors are essential to the continuity and progress of cosmic and organic life.

[2] W. Patten, "The Grand Strategy of Evolution," R. Badger, 1920.

Man ultimately came into being as the ripening product of this compelling predetermined order, chemical, terrestrial, organic and social. It matters little when or whence he came, or what was the color of his skin or the shape and thickness of his skull, compared with the fact that his whole structure and behavior were the visible expressions of a cosmic creative method that will suffer no other method to endure.

When first we see him, man was fully erect and distinctly different from all his predecessors in that he was provided with three highly cooperative betterments for the larger give and take of social life: (1) hands specially fitted for the making, distribution and exchange of detachable personal properties; (2) articulate speech for the transmission and exchange of personal experiences, knowledge or ideas, and (3) more "brains," far better adapted than ever before to perceive and utilize the larger ways and means of living.

The foundations of all these complex organs of transmission and reception, such as hands, tongue, larynx, ears, eyes and brains, were laid down in their present anatomical relations hundreds of millions of years beforehand in the fishes or even in still more primitive forms.

Thus, with the advent of man, new kinds of social tissues and social functions arose which formed a new system of social metabolism, with new opportunities for adaptation and for profitable variation and conservation. In fact, it was the advent of a new kind of heredity and the initiation of new kinds of heritages.

This new phase of life stands on a far higher level than ever before. It differs more widely from the old life, in its po-

tentialities at least, than apes do from fishes. It has produced, in a relatively short time, a greater revolution in the art of living, a greater change in the complexion of terrestrial life, than any other known organic innovation.

Apes, reptiles and fishes, for example, are perpetuated by means of special kinds of germ-plasm. Each one of these groups of animals advances on a common front under the bondage of similar germinal heritages. With mankind it is different. All the different genera, species and varieties of mankind, in addition to their common germinal heritages, have this new system of cultural heritages by means of which the profits of individual lives are eventually redistributed, communized, socially assimilated and regenerated in an endless variety of new forms.

These new cultural factors are largely external and quite distinct from the germinal factors in sexual reproduction. Nevertheless they greatly enlarge the scope of heredity. They help to renovate and perpetuate the social life of mankind, as a whole, in much the same way that the living germ-plasm helps to renovate and perpetuate the life of individual organisms.

Thus all kinds of human beings are functionally unified by their cultural as well as their germinal heritages. They advance, ameba-like, on a wavering front to higher levels. Each individual, under the bondage of his germinal and cultural heritages, is a debtor and a creditor, a creator of, and himself created by, the system of realities of which he is a living part.

No man can change or escape from this basic method of life and growth. Man himself is a miniature expression of it, and can do his creative work in no other way.

And so primitive man, dimly perceiving the provisioning artistry in the activities of a mother-like nature, began some millions of years ago to wonder what it was all about. Unwittingly imitating the alluring model always before him, he also became an artist and an anticipating provider, an ever hopeful visionary, always seeking, with his clearing vision of realities and his augmenting powers, for still larger ways and means of living.

With infantile simplicity, he artfully tried to check or stimulate the activities of his natural mother. He made crude pictures of nature's familiar products, mocked them, threatened them with disaster or summoned them with childish gifts, with wailings and gesticulations, to do what he most desired. Then, confusing fiction with reality, he naïvely tried to substitute his totems, amulets and other symbolic toys for the cosmic powers they represented, hoping thereby to capture the unattainable.

By this experimental monkeying with the chains that bound him, the scientific ape-man became a magician, sorcerer and medicine-man, a clever juggler with materialistic symbols, a befuddled mystic misled by the glimmerings of an immature imagination, vainly seeking to find an effortless way to reproduce the creative miracles of nature or to escape from the bondage of causal realities. The hard-boiled scientist who to-day dreams of creating life in a test-tube is one of the surviving types of befuddled medicine-men.

Believing that he had finally discovered the secret of creation, he proclaimed himself a god, and as a warrior, prophet or king sought to conquer the world for himself and his next of kin. But man was slowly learning, oh, so very slowly learning, that he could not get what he wanted in that way. A better imitation of the creative way, a better matching of human logic with nature's logic was requisite.

He was slowly learning that he could never conquer nature. Nature always

conquered him. He was learning that to win, he must first submit, or adapt his ways to her ways by the conquest of himself. For many thousands of years, thoughtful men the world over, under the pseudonym of religion, were unconsciously recognizing the moral and ethical principles of evolution—such as the necessity for hard labor, self-sacrifice, mutual service, righteousness and provision for the future—and were building these basic virtues into the foundations of their science and art of living and dying.

With the clearer recognition of these creative methods, and a better application of them, the era of sorcery is slowly giving way to the era of scientific maturity.

The spirit of science is the spirit of evolution visibly expressed in the life and growth of mankind. The ideal scientist—never an actuality, even though every living thing is in some respects a scientist—has all the great creative functions of nature cooperatively united in himself. For the scientist, even the least of them, is something more than a recording secretary of careful observations, measurements and experiments. He is primarily a knower of worldly ways and a self-adaptive interpreter of what he knows, just as cats and dogs —all of them good scientists in their respective specialties—very well know each other's ways and, rightly interpreting the signs and omens in their world of affairs, adapt themselves beforehand to coming events.

And the human scientist, in so far as he is self-adaptive, is an artist and an artisan, a practical man laboring with hard realities rather than a rhetorician playing with the verbal symbols of his own mental attitudes, or a circuitous thinker vainly chasing the tail of his own thoughts. He seeks rightly to interpret the signs and omens of what is going on within and about himself in order that he may adjust himself to a growing world in a more workable and profitable way.

As an interpreter of his accumulated store of knowledge, he is in his own right a philosopher and theologian of sorts, with all those longings, sensuous convictions and self-satisfying reactions to the apprehension of fundamental truths commonly called religion.

He is also a prophet crying in a wilderness of stubborn realities and uncoordinated experiences, a propagandist, path-finder, reformer and peacemaker. For why should man seek for truth and understanding, if not to sow it and use its fruits to mitigate the inevitable conflicts of life? But the seed can never know its own fruit. So the modern scientist, like primitive man, is still wondering what life is all about and what he *ought* to do about it. Nay, what he *must* do in order to live and grow.

THE EMBRYOLOGICAL BIOCHEMISTRY OF THE DEVELOPING HEN'S EGG[1]

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THE living organism can be distinguished from the lifeless by its inherent property of reproduction. In the higher forms of animal life two cells are usually considered necessary for this process, although possibly the only essential reproductive cell is the egg. The fertilizing cell has, in a few instances, been replaced by simple chemical compounds. The fertile egg may be considered to be a bit of living protoplasm with a highly specialized function, namely, that of reproducing an individual whose organization and characteristics are like those of the species from which the egg arose. We know that the highly organized individual does not exist preformed, minute in size, in the egg, but that an infinite number of physical, chemical and morphological changes must occur before the embryo can emerge fully formed. Of the morphological changes much has been learned in the last century, but of the physical and chemical or physicochemical changes very little has been learned—indeed, Needham closed a review article in 1925 with a remark of William Harvey's: "Neither the School of Physicians, nor Aristotle's discerning brain, have yet disclosed how the hen doth mint and coin the chicken out of the egg."

Some of the obstacles which hinder advancement in the knowledge of embryological biochemistry are rapidly being overcome, chiefly because of the remarkable accuracy of modern microchemical methods, although many difficulties still remain. Most of the investigations that have been made on the chemical changes which occur during embryonic development have been made on the easily available hen's egg, consequently most of the conclusions are drawn from these investigations. There are numerous variable factors which can modify the composition of the egg as well as the rate of development of the blastoderm. The amount of yolk, albumin and water as well as the thickness of the shell may vary with the diet, season of the year and general condition of the animal producing the egg. The velocity of the passage of the egg down the oviduct where the albumin is obtained, the period intervening between the time of laying and the time of collecting the egg, the temperature and humidity of the environment—all are factors which may cause individual variations during development. Fertilization in the upper part of the oviduct initiates development which continues for from eighteen to thirty-six hours, the time required for the complete formation of the egg by the hen. Sometimes the egg may not be laid for forty-eight hours or longer after it has been completely formed, consequently when it is laid development of the blastoderm may have already passed the stage of differentiation into the three germ layers. Such variations in the length of time which the egg remains in the hen make it very improbable that two eggs synchronously laid will contain embryos of exactly the same age. Poultry farmers recognize not only these "body

[1] A large amount of the information in this article has been obtained from the papers of J. Needham published in the *Biochemical Journal*, *Physiological Reviews* and the *British Journal of Experimental Biology*, as well as the papers of H. A. Murray, Jr., published in the *Journal of Experimental Physiology*.

heated" eggs but also the fact that, if a hen sets on the eggs for a time after laying, development will be further advanced than the average.

Another of the difficulties encountered is the fact that the investigator is still very much in the dark regarding the composition of the more important constituents of the egg itself. This is especially true of the proteins, notwithstanding the fact that much work has been done. Very little is known concerning the composition of the albumin, although it is one of the few proteins than can be readily obtained in quantity in a pure crystalline form. Less is known about the yolk proteins, the proteins of the membranes, the proteins of the shell, the pigments and some of the lipids. Until the "static" chemistry of the egg is better understood great precaution is necessary in the interpretation of measurable metabolic changes.

A difficulty more significant than these already mentioned is the indefiniteness of morphological boundaries. Many investigators are not careful to state exactly what procedures were followed. In cases where separations are made into embryo and remaining material, with which should the membrane of the allantois be included? When the shell and its contents are separated, with which should the outer and inner shell membranes be included? When the yolk sac is being withdrawn into the body of the chick, where does yolk end and intestinal contents begin? As Needham has pointed out, the only solution is to adhere strictly to well-thought-out boundaries and to state, when describing the work done, exactly the procedure followed.

The correlation of chemical with morphological changes, in any case, is difficult. The embryologist has been interested only in the early stages of development up to about the ninth day when the embryo becomes adult morphologically, consequently very little is known about the changes in the size and development of the organs in the later stages. However, it is in these stages that the greatest chemical changes occur.

Regardless of these difficulties, remarkable advances have been made in recent years in embryological biochemistry. One of the earliest observations recorded was that the egg normally loses approximately five grams in weight during the developmental period. Nearly a hundred years later it was clearly demonstrated that this loss in weight is almost entirely dependent on the humidity of the surrounding atmosphere. Strange as it may seem, between 1818 and 1840 four different investigators showed that the egg could develop normally in an inert gas such as hydrogen or nitrogen, immersed in oil or coated with paraffin. However, this was soon disproved, and it has been demonstrated in various laboratories that from 3 to 3.5 liters of carbon dioxide are excreted by the egg during development and that a corresponding amount of oxygen is absorbed. Near the end of the incubation period as much as 350 to 400 cubic centimeters of carbon dioxide are exhaled per day, while in the early stages very small quantities are exhaled. It was, likewise, soon demonstrated that all the shell, with the exception of the small part covering the air space, could be varnished and the chick still develop normally. It is through this part of the shell that the embryo breathes.

The question immediately arises, what are the substances used by the embryo in the production of this large amount of carbon dioxide? Is it protein, fat or carbohydrate, or some of all three? Needless to say there are no methods delicate enough to detect the chemical changes that occur during the first few hours after fertilization. Consequently, very little chemical investigation has been made from the time of fertilization to the end of the third or fourth day. Until very recently it was generally be-

lieved that lipids were the entire source of energy for embryonic development. This view arose from the fact that when lipids were determined in the fresh egg and in the fully developed embryo some had been lost, actually about 2.4 grams as an average. This figure corresponded satisfactorily, on calculation, with the loss in carbon dioxide and heat output of the embryo. The correspondence of the figures was not very exact but was thought close enough to show that lipids were the only source. Careful examination of the respiratory quotient after the seventh day gave a value of 0.73, which, unless something very strange was happening, must be considered close enough to the theoretical value for lipids. In the words of Needham, "It might have been doubted, however, that fat was the only important source of energy: there were hints to the contrary in the literature. William Harvey had said, 'and therefore the yolke seems to be a remoter and more deferred entertainment than the white, for all the white is quite clean spent before any notable invasion is made upon the yolke.'" Urea and a considerable amount of uric acid were early obtained from the allantoic and amniotic fluids so that there should have been no doubt of the metabolism of proteins.

Although lipids may have been considered the predominating source of energy, especially in the later stages, it should never have been so considered in the early stages of development, for much evidence points to the use of carbohydrates in this period. The respiratory quotient during the first five days is sometimes as high as 0.95 and thereafter decreases to approximately 0.70, indicating quite clearly that glucose or some other carbohydrate is being burned in the early stages of development followed by the combustion of lipids. This harmonizes with the fact that in the fresh egg there is about 0.5 gram of free glucose present and at the end of five days only about 0.1 gram. Simultaneously with the disappearance of glucose the lactic acid content of the egg rises, reaches a peak and immediately falls to the previously low level. The peak is attained about the fifth day. Also when the glycolytic behavior of embryonic tissue is examined *in vitro* it is found that there is a marked preferential consumption of carbohydrate by the tissue of the three to five day chick.

Still more recently very convincing evidence has been obtained that proteins are also used for energy during the early stages of development. It has long been known that no nitrogen has been lost from the developing egg, consequently the estimation of ammonia, urea and uric acid, end products of protein metabolism, should show definitely whether or not proteins are being burned. Such estimations have been made. The ammonia increases throughout the entire period of development, but in comparison to the dry weight of the embryo it reaches a peak on the fourth day. The amounts of ammonia excreted, however, are very small. A period of intensive output of urea has been shown to occur between the fifth and ninth days. After that time its production does not keep pace with the growth and differentiation of the embryo. The peak of production in comparison to the dry weight of the embryo is on the ninth day, five days after that of the ammonia. The period of intensive uric acid production is from the seventh to the eleventh day, after which the uric acid production does not keep pace with the growth of the embryo. The uric acid peak is seven days later than the point of maximum intensity of production of ammonia and two days later than the same peak for urea. This period of maximum production of nitrogenous waste products, hence the period of maximum intensity of protein combustion, occurs between the eighth day and the tenth day, and this is midway between the periods when carbo-

hydrates and lipids are, respectively, the predominant sources of energy. The protein nitrogen lost by combustion during development amounts to about 7 per cent. of the total protein nitrogen present in the beginning and 3 per cent. of the total foodstuffs burned.

This observation of a succession of energy sources leads to another question. Is it due to the available food supply present in the egg (ovogenic), or is it the order preferred by the embryo itself (embryogenic)? The evidence is in favor of the latter. Large amounts of lipids are always present; all the free carbohydrate is not consumed until the twelfth day and the injection of glucose does not alter the uric acid curve. This is good evidence in favor of the view that the embryo and not its food supply controls the situation.

Energy Sources and the Theory of Recapitulation

The theory that the development of the individual repeats briefly the evolution of the species has been widely accepted by embryologists. It is based on the comparison between the embryonic development of the individual and the comparative anatomy of the species to which it belongs. There is very little biochemical evidence for such a phenomenon; however, it is possible that the order in which the developing embryo selects its foodstuffs may have a recapitulatory significance. The order, carbohydrate, protein, lipid, being the order of selection by the embryo, is also the order of solubility in water, of oxygen content, of ease of digestibility by enzymes of the gastro-intestinal tract and the ease with which they are synthesized by solar energy. Some significance may also be attached to the order in which the nitrogenous end products of protein metabolism are produced. The simplest product of deamination of amino acids is the first to appear, and the most complex is the last. Ammonia, the most soluble and the highest in nitrogen content, is produced first, while uric acid, the most insoluble and the least in nitrogen content, is produced last and accounts for over 90 per cent. of the nitrogen excreted by the chick embryo. Other evidence for the recapitulatory phenomenon is that the invertebrate embryo is relatively richer in sodium chloride than the newly born, the chick is lower by half at fifteen days than at the beginning, the water content gradually decreases, the enzymes of the adult are gradually formed and the membranes of the eggs of some species are not keratin but resemble a mucin. It may be that the ovomucoid of the hen's egg is phylogenetically reminiscent of the time when it was used as a membrane. Further biochemical evidence of this theory will be interesting especially with regard to the succession of energy sources in other embryos and the order of production of nitrogenous waste products.

Some Specialized Phases of Metabolism

A number of chemical changes have been investigated which indicate specialized types of metabolism. Creatin, a substance related to muscular development, is entirely absent from the fresh egg, but its presence has been demonstrated as early as the fifth day and it gradually increases in amount thereafter. Several of the amino acids, substances formed in the breakdown of protein, have been studied. Some of them remain constant throughout the entire period of development, while others show a marked decrease in amount. Inorganic phosphates increase during development, while there is a corresponding decrease in the organic phosphorus. There is a transfer of calcium from the shell to the embryo. The total cholesterol content does not change, although there is a marked change in most of the other fat-like sub-

stances. The purine bases are entirely absent from the fresh egg, but there is a very marked production of them during development. This is without doubt related to the fact that these substances are constituents of the nucleic acid which is always found in cell nuclei. With the rapid increase in the number of cell nuclei of the embryo during the developmental period, it follows, *a priori,* that the purine bases must increase also. Many other chemical changes have been studied, but the findings are so inadequate and contradictory that no definite conclusions can be drawn until these changes have been much further studied. Still other phases of embryonic metabolism have not been investigated at all.

In all the biological sciences the more advanced stage has been the first investigated. Anatomy and morphology preceded embryology; the study of the methods of curing diseases preceded by centuries the practices of preventive medicine; likewise the chemical investigations of physiological phenomena have been confined almost entirely to the changes occurring in the normal adult and attempts are made to interpret all change in terms of the normal adult individual. The fact that a certain change takes place in the embryo does not necessarily mean that the same change will occur in the adult. The fact that a certain phenomenon appears in the chick embryo does not mean that the same thing will occur in the development of the embryos of other species. Neither does the fact that a chemical change occurs in the adult mean that the same reaction will occur a decade in in the future. Life is undoubtedly a procession of physical and chemical changes, some certainly continuing throughout life and into the future generations, while it is just as certain that others continue for a time, then cease, while new ones begin. Consequently any advance in our knowledge of embryological biochemistry is a step in advance toward a better understanding of physiological phenomena in general. The large number of investigations that are being made in this field at the present time give rise to the hope that in the future that remarkable transformation of the inert materials of the egg into the fully developed chick will be better understood and the remark of William Harvey will no longer apply as it still does to-day.

A DISEASE AND EVOLUTION

By Dr. PHILIP R. WHITE

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THERE are certainly more named diseases, of ourselves and of our domestic creatures, plant or animal, to-day, than there were a century ago. Whether there has been a real increase in the number of maladies or only a segregation and renaming of old ones I will leave to the pathologists to decide. But the fact remains. And for any given host there are more diseases. Perhaps plants (for as a botanist I ought to confine myself to them) are evolving susceptibility to sicknesses once strange to them but existent in their neighbors, in the same way that immunities may be evolved. If so, under the old, pre-human order, such degenerates would have been doomed to destruction and owe, then, their preservation to us. Perhaps we are bringing diseases from far countries, unwittingly implanting them on hosts which, being "unaccustomed" to them, have not the resistance to withstand them. Certainly we have enough examples of that to our discredit. And perhaps, too, we are bringing susceptible but previously unexposed plants into regions infected by unrecognized

ILLUSTRATION FROM GONZALES "HISTORIA, ETC."

EDITION OF 1723. IT OBVIOUSLY DOES NOT ILLUSTRATE THE PRINTED MATTER OF THE BOOK. THE TWO TREES AT THE LEFT ARE THE ARTIST'S IDEA OF BANANAS, THOSE AT THE RIGHT PROBABLY PAPAYA. INCIDENTALLY, THE BLACK BOY IS NO MORE AN INDIGENE THAN IS THE BANANA.

maladies, maladies left unrecognized because attacking only weeds of no consequence to us and hence attracting no attention. Whatever the real explanation or explanations, man must acknowledge his major responsibility. He does not ordinarily recognize any obligation to the universe to correct these slips, but sometimes it becomes highly desirable for him to do so. And usually in the end he is successful, I think.

About forty years ago in some of the banana plantations of Panama and Costa Rica there appeared a disease which is now known as the "Panama disease." Bananas had not yet become a household staple, as they are to-day; plantations were small and scattered; the infected areas were isolated. The disease did not then attract much attention. But along with the growth of importance of the host, the disease grew in importance and geographic distribution even more rapidly, so that fifteen years later it had become an important factor in the development of a large industry.

The origin of the disease is buried among the myriad other secrets of the tropic jungles. First noticed, as I have said, in Central America, first described from far-off Hawaii and to-day rampant through most of the New World tropics, the literature can still say of the Old World continents only that it "probably" exists there. It may have come from the Old World to find a too tender host in the probably American-bred varieties of bananas, or with equal possibility it may have lain in ambush for centuries in those wild relatives of the banana, the Heliconias, which are such prominent features of the lowland swamps of the American tropics. Whatever its origin, the disease has definitely fastened itself on a crop which has of late become one of the staples of the American cuisine, and though it has by no means come so near annihilating its host as has the chestnut-blight, it can be compared only to that malady in the violence of its depredations.

If we were dealing with an animal disease and had isolated the offending organism as we have here (for *Fusarium cubense,* the causal agent, was isolated many years ago), even the layman would immediately suggest several potentially valuable methods to be employed. Many such diseases may be controlled with disinfectants of various kinds; others by vaccination and the development of acquired immunity; others yet by antitoxins, the transfer of an immunity from one creature to another. Sometimes there is a carrier whose elimination offers a method of control. Practically all animal diseases, where the life history of the causative agent is known, are amenable to one or more of these methods. But the matter is not so easy with a plant, especially this one. Disinfection of the plant itself is useless, since the disease enters through the soil, which can not be sterilized over large tracts. No antitoxins or vaccines are known for *Fusaria,* and were they known there is no unified circulatory system in the plant to distribute them to the affected parts. There is a carrier, but that carrier is every drop of seepage, the run-off of every rain, the very life-blood of the plant itself. We can not sterilize all the water fed to the plant as we can our drinking water. Altogether the problem of controlling such a disease appears at first quite hopeless.

There is one slim branch reaching above the first wall which bars our path by which, if we are lucky, we may perhaps swing over to firm ground again. When a child is vaccinated for smallpox he usually becomes mildly ill. We say that the vaccination has taken. But among a hundred children there will always be a few who show no initial effect, even under increased doses. The vaccine will not take. They are nat-

urally immune. Now the great mass of work done, especially in the last thirty years, on animal and plant breeding has convinced us that all characteristics of living creatures which are not directly traceable to their surroundings are heritable and may be passed on to their genetic descendants. They, of course, will frequently not be passed on to all descendants, but the important point to us is that they may in any case be transmitted. If a child is immune to smallpox his children will not necessarily be, but they have a better chance of being naturally immune than the children of a child in whom vaccination took. And we are hunting for any chance. But to return to the banana. There are varieties known which are resistant to the Panama disease, but unfortunately they are not very desirable commercially because of other traits. And there are other varieties which are desirable commercially, but again, unfortunately, these are just the ones most susceptible to the disease in question. Knowing the facts of inheritance we might (theoretically) take a poor but resistant variety as one parent, and a good but sickly variety as the other and perhaps (and as long as we can say perhaps, even though it may not carry much conviction, the attempt is worth while) we may get a few descendants out of many which will be both good and resistant. But here again we are confronted by another apparently insurmountable and impenetrable wall for—anomalous as it may seem—no otherwise good banana ever had any progeny to be immune! For the commercial banana is reproduced vegetatively only, by cuttings. It is, as we say, parthenocarpic, producing fruit without viable seed, as most of those of my readers who have eaten bananas will agree. And, what is quite obvious, though you may not have thought of it, if it did produce seeds, it would be no good as a fruit, at least no better than Proserpina's pomegranate (*pomme grainé,* or seedy apple). Now, if by some hook or crook we can inveigle a good banana into having progeny by an immune species or an immune species by a good commercial variety (improbability No. 1), and if further, after we have succeeded in combining our desired characteristics in the way we want them, we can then guarantee that our product will not continue to have progeny (seeds) to spoil the result (improbability No. 2), then and only then will we have reached our goal.

As we have said, the varieties of bananas in which we are interested do not bear seeds. In fact, I imagine few of my readers have ever seen a banana seed. Yet the mere fact of bearing seeds is the only universal characteristic of the higher plants. Is it conceivable that nature has made an exception of this one group of plants? Actually, it is unnecessary to resort to any such far-fetched conclusion. Many, in fact, the majority, of bananas do bear seeds but, quite as we should expect, these varieties are valueless commercially and consequently known only to the initiated. Somewhere, somehow, and as H. G. Wells would say, somewhen, the transformation from seedy to seedless types has occurred, perhaps once, more probably many times. And since nature has made the transformation, perhaps if we can discover the secret of her method we may be able to reverse her process, to produce our first good-immune progeny and then, doubling back on our tracks again, obtain in the end our final seedless-good-immune result. I have set down an appalling number of "perhapses" but science never despairs of doing anything that nature has done before, though the cost may be so prohibitive as to make it inexpedient to do so.

"Somewhere, somehow, somewhen." Where and when are in the past, history, and if it is sufficiently ancient, archeology, and if even more ancient, paleontology (since we are dealing with at least

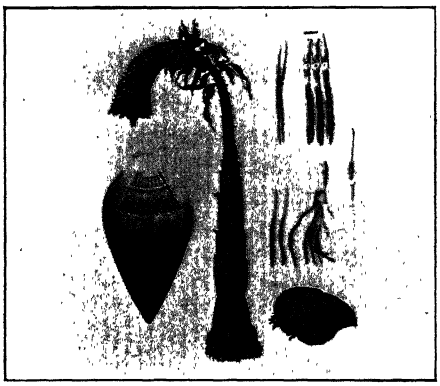
one-time living creatures). So we shall have to call upon the fellow sciences of geology, archeology, history and ethnology to see if they can not help us burrow under this second wall.

Perhaps a million and a half years ago, in Tertiary times, somewhere nearly coeval with the Peiping man, there lived on the borders of the jungle in what is now Colombia, in South America, a banana, the first to leave us any trace of its existence. It was not such a one as American tourists know in the southlands but more like that seen by Bruce in his search for the sources of the Nile,[1] rearing an enormous, solitary (lacking in "suckers") stem up to form a single thousand-flowered inflorescence with many small fruits the size of one's thumb. Each fruit was quite filled by a small number of black, very hard, smooth seeds, quite inedible. All this we know from the fossil remains, for though only these seeds have been preserved to us, they are sufficiently like the varieties found to-day, in the uplands of Abyssinia, as almost to cast doubt on the authenticity of the fossils![2] In the whole group of bananas to which they belong, only the base of the pseudostem is eaten, and they are only distantly re-

WHEN you make ufe of the Enfete for eating, you cut it immediately above the fmall detached roots, and perhaps a foot or two higher, as the plant is of age. You ftrip the green from the upper part till it becomes white; when foft, like a turnip well boiled, if eat with milk or butter it is the beft of all food, wholefome, nourifhing, and eafily digefted.

From Bruce, "Select Specimens of Natural History."

lated to our edible forms. Curiously, these seeds are the only fossil remains left to us anywhere in the world, though they, like the fossil camels of our own Southwest, are in a region now long since abandoned by their race. So we have no geological sign of when, where or how sterility originated in the tribe.



DRAWING MADE IN ABYSSINIA ABOUT 1780

FROM JAMES BRUCE, "SELECT SPECIMENS OF NATURAL HISTORY."

MUSA GLAUCA, THE "VIRGIN BANANA" PROBABLY THE Τάλα OF MEGASTHENES, PHOTOGRAPHED BY THE AUTHOR ON THE UNITED FRUIT COMPANY'S EXPERIMENTAL PLANTATION AT CHANGUINOLA, ALMIRANTE, PANAMA, AUGUST, 1927.

[1] James Bruce, "Select Specimens of Natural History Collected in Travels to Discover the Source of the Nile in Egypt, Arabia, Abyssinia and Nubia," J. Ruthven, Edinburgh, 1790.

[2] E. W. Berry, "A Species of Musa in the Tertiary of South America," *Proc. Nat. Acad. Sci.*, 11: 298–299, 1925.

—*Portions of plates 6 and 45, Vol. I, John Griffiths, London, 1896–7.*

PAINTINGS OF THE BUDDHIST CAVE TEMPLES OF AJANTÂ, KHANDESH, INDIA. THE TYPICAL COILED LEAF OF THE BANANA FORMS A CHARACTERISTIC MOTIF IN BOTH PICTURES.

Such chronologies as I am trying to construct are always, at first, fragmentary, but not often so much so as this proves to be. We must leap the whole life span of the human race and half circle the globe for our next point, to the hills of west-central India, in the fourth century before our era. Here, frescoed on the walls of the wonderful cave temples of Ajantâ, in Khandesh, we find pictures of the king's gardens, and in them, quite unmistakable, our bananas; but no fruits are shown, so that these figures are probably of bananas of the Abyssinian type like those of Colombia. What happened in the interim between our Colombian fossils and the Indian monarch's garden? The jungle has buried that secret, perhaps for all time. Nor does subsequent history give us any sign of any more recent example of the sterilization process. A century later (303 B. C.) Megasthenes, then ambassador from Macedonia to Sandrocottus at Palimbothra on the Ganges,[3] described a banana in which, as in the Abyssinian one, the stem (as he says, the inner bark) was eaten, calling it *Τάλα*.[4] Theophrastus does not name it in any extant fragment but describes the leaf.[5] Pliny,

[3] Strabo, ''The Geography of Strabo,'' translated by Horace L. Jones, the Loeb Classical Library, G. P. Putnam's Sons, New York, 1917: *ἐπέμφθησαν μὲν γὰρ εἰς τὰ Παλίμβοθρα, ὁ μὲν Μεγασθενης πρὸς Σανδρόκοττον*—2. 1. 9.

[4] Megasthenes: *οὕτω μηδὲ 'Ινδαῖσι πόλιας εἶναι μηδὲ ἱερὰ θεῶν δε δομωμένα, ἀλλ' αμπέχεσθαι μὲν δορὰς θηρίων ὅσων χαταΧτὰνοιεν. σιτέεσθαι δέ τῶν δενδρεων τὸν φλοιόν. χαλέεσθαι δὲ τὰ δένδρεα ταῦτα τῇ 'Ινδῶν φωνῇ Τάλα. χαὶ φύεσθαι ἐπ' αὐτῶν χατάπερ τῶν φοινιχων ἐπὶ τῇσι χορυφῇσιν οἷα περ τολύπας.*

Karl et Theod. Müller, ''Fragmenta historicorum graecorum editore Ambrosio,'' Parisis, Firmin Didot, 1848–1874.

[5] Theophrasti Eresii, ''De Historia Plantarum,'' Lib. I, Cap. 4, 5–6. Gottlieb Schneider, Lipsiae, 1821.

using Megasthenes' name changed to *Pala,* assumes that Theophrastus' interpretations of his informant's statements were wrong and that where he speaks of leaf, flower and fruit of three trees he actually was describing the three parts of a single plant.[6] If Pliny is right, then Theophrastus does speak of the fruit of the banana, telling how Alexander for-

a B. Mauzi, vel muzi. *De* a [*musa.*] *Cap* 491.

Musa quid est? nota est. *Operationes, & proprietates.* b [Nutrit velociter,] & est lenificatiua. & multitudo eius generat oppilationes, & addit in cholera, & phlegmate secũdum complexionem. *Membra anhelitus, & pectoris.* Confert adustioni gutturis, & pectoris. *Membra nutrimenti.* c [Stomacho conueniens est, & multitudo eius] stomacho est grauis valde. Et oportet quidem, vt sumat post ipsam calefactus oxymel cum seminibus, & infrigidatus, mel. *Membra expulsionis.* Augmentum efficit in spermate, & conuenit renibus, & prouocat vrinam.

b B. Nutrimentum eius est paruum.

c B. est grauis stomacho prę-cipue cũ ex ea multũ assumitur. Multitudo enim eius.

From Ibn Sīnā, "Avicenna medicorum Arabum principis," edition of 1556. The original Arabic edition was about 1020.

bade his soldiers to eat it as causing dysentery. But I am inclined to believe that Theophrastus was right, in which case the banana he referred to was again of the Abyssinian type. Even those masters of early medieval botany, Avicenna[7] and Ruelio,[8] do not make it clear whether they refer to fruit or stem, and Serapion[9] definitely says that it is the stem and "heart" that was used. It is not until the early part of the sixteenth century with Garcia da Orta[10] and Fernandez[11] that we find the fruit itself referred to definitely as appearing, first in Venice, then in Spain, brought there from Alexandria and thence from India.

MVSA.

Auz.1.Musa Abẽmesuai ẽ calm ĩ medio primi grad' hu midũ ĩ fine eius nutrit pa℞ & pro prietas eius ẽ cõfere ardori q ẽ ĩ pe ctore & pulmõe & uesica & molit uẽ trẽ & qui utitur eo multũ facit gra uedĩem. ĩ stõaco & opilatiõem ĩ epa te & oportet ꝙ ille qui utitur eo mĺ tum si cũplio eius ẽ frigida ut bibat post ipium melicratum aut oximel aut ziziber cõditũ Sĩdaxar auget fetũ ĩ uẽtre matricis Alcbile be mẽ ẽ medicia bõa pectori & rẽibus & puõcat urĩam Liber de medi cĩa ãtiqua excitat libidinẽ & est gra ue stomaco.

From Ebn Serabi, "Liber Serapionis agragatus in medicinis simplicibus," Cap. 80, edition of 1473.

[6] C. Pliny, "Plinii Naturalis Historia," XII, 2–6 (6–13). D. Detlefsen recensuit Berolini. Apud Weidmannos, 1886.

[7] Husain ibn 'Abd Allah Ibn Sīnā, "Avicenna medicorum Arabum principis, Liber canonis." Basileae per Ioannes Hernagios, 1556.

[8] Joannes Ruellius, "De natura stirpium libri tres." Ex officina S. Colinaei: Parisiio, 1536.

[9] "Abēmesuai ē calm ī medio primi grad' humidū ī fine eius nutrit. . . ." Ebn Serabi, "Liber Serapionis agregatus in medicinis simplicibus translatio Symonis Januensis interprete Abraam judeo Tortuosiensi de arabico in latinum." Mediolanus, A. Zarotum, 1473.

[10] "R– O fructo que em Italia chamam *musa* é por ventura este figo? O– Eu como não fui a Italia não o sei bem sabido, porem soube aqui de alguns Venezianos aqui moradores, que essa fructa ha em Veneza." Garcia da Orta, "Coloquios dos simples e drogas he cousas medicinais da India compostos pello Doutor Garcia de Orta." Johannes de Endem, Goa, 1563.

[11] "E tambien he oydo deçir que los hay en la cibdad de Almería en el reyno de Granada, é dicese que de alli passó esta planta á las Indias, é que á Almería vino del Levante é de Alexandría, é de la India oriental. He oydo á mercadores genoveses é italianos é griegos que han estado en aquilas partes, é me han informado que esta fructa la hay en la India que he dicho é que assi mismo es muy comun en el Egipto, en espeçial en la cibdad de Alexandria donde á esta fructa llaman *musas.*" Fernandez (Gonzales F. de Oviedo y Valdes). "Historia general y natural de las Indias, Islas, y Tierra Firma del Mar Oceano." Imprenta de la real Academia de la Historia, Madrid, 1853.

With the voyages of Vasco da Gama and others it was brought to the west coast of Africa, to the Gran Canari, "las Islas Fortunadas" and elsewhere. Simultaneously with the sudden expansion of the horizon of the world we find this most useful of all plants (I say that advisedly[12]) carried from the Canaries to Santo Domingo in 1517.[13] Three years later it completed its voyage to the American continent when it was carried to Peru.[13] Von Humboldt[14] tries to establish its American origin, but the only statement I can find in the authority he cites—Garcillasso de la Vega[15]—can not be interpreted as even implying such a thing as far as I can see.[16] Thus it returns after fifteen hundred millennia to the home of its Tertiary ancestors, still keeping the secret which we sought to discover. Geology, archeology and history have helped us not at all.

Linguistics is equally useless, for though we can trace Megasthenes' Τάλα and Pliny's *Pala* to the more modern palam, palon,[17] vala, Kala, Kadla, Kadali, Kadli, Kali (which is evidently the form rendered in the sixteenth century Portuguese of Garcia da Orta[18] as Quelli), Kladi, Klui, Chuoi, etc., and while the Malay pisang of to-day goes back at least to da Orta's Piçam, these tell us only that some banana was a staple at the time these languages arose, at least two millennia B. C. and probably much earlier than that.

My allies have failed to dig under my second wall then. There remains only one recourse. By some scientific third degree we must interrogate the banana itself concerning its past, hidden thus in antiquity. And since it is with the particular variety of commerce, the Gros Michel, that we are especially interested, it is that variety on which we shall center our interrogation. It is here that I can return to my rôle of botanist.

The details of my questioning can be ignored.[19] But the findings themselves are important. We have good reason to believe to-day that every tiny cell of every living creature, whether plant or animal (though we are not quite sure about bacteria and a few others) carries within itself all the potentialities of the creature as a whole, and that these potentialities are the impress of the whole past history of the race (not to imply Lamarckism). Furthermore, these potentialities are born, not in the cell as a whole or even in the entire nucleus, but in those special little packets called chromosomes. If we could read the inscriptions on these cylinders, as we have those

12 "For that is the fruit they use most at the Indies—they serve them as bread, yea they make wine of them. They eat this fruite rawe like other fruits; they likewise roast it, and make many sorts of potages and conserves and in all things it serveth very well. . . . If this plant were fit for fire it were the most profitable of all others." José de Acosta, "The Natural and Moral History of the Indies," (translated by Edward Grimston, 1609), 1590.

13 Fernandez, *loc. cit.*, "fué traydo este linage de planta de la isla de Gran Canaria, el año de mill é quinientos y dies y seys años, por el reverendo padre fray Thomas de Berlanga de lo Orden de los Predicadores, á esta cibdad de Sancto Domingo, é desde aqui se han extendido en las otras poblaçiones desta isla y en todas las otras islas poblades de christianos, é los han llevado a la Tierra-Firme, y en cada parte que los han puesto, se han dado muy bien."

14 Alexander von Humboldt, "Atlas geographique et physique du royaume de la Nouvelle Espagne," Paris, 1811.

15 Garcillasso de la Vega, "Primera parte de los Commentarios reales," Oficina real, Madrid, 1609.

16 Presenteron muchos Conejos caseros, y campestres, muchas Perdices vivas, y muertas, y otras Aves del Agua, innumerables Pajoros menores, mucho *Mais* en grano y mucho amasado en pan, mucha *Fruta* seca, y verde, Mucha *miel* en Panales, y fuera de effos, mucha *Pimienta* de los Indios, que llaman Uchu, cantitad de su Brevaji asi hecho de *Maiz*, como del *Grano*, que llaman Mulli. . . . En suma, no dejaron cosa de las que pudieron traer, que no la trujesen. (Cap. XVII.) Una Embaja, con grandes presentes, que il Inca hiço a los Espanoles.

17 Fernandez, *loc. cit.*

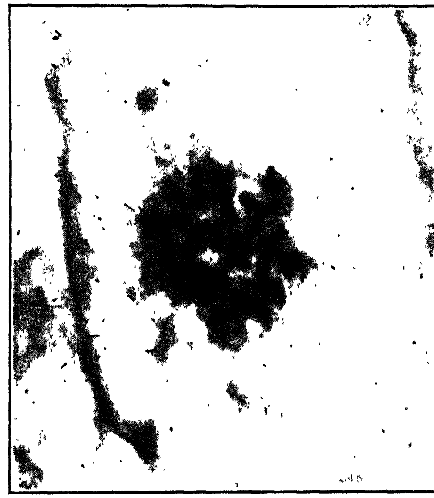
18 Garcia da Orta, *loc. cit.*

19 Philip R. White, "Studies on the Banana," *Zeitschr. f. Zellforsch. u. mik. Anat.*, 7: 673–733. 1928.

of Babylon, we could know all the past history of the race, from the creation. I am not so sanguine as to hope for that. The inscriptions themselves must remain sealed to us, for a time at least. But we can read something from the positions in which we find these cylinders lying.

As most of my readers know, when an egg[20] is fertilized by a sperm,[20] the egg carries with it a certain number of these packets bearing half the characteristics (half the past history) of the mother,[20] and ordinarily the sperm carries an equal number of packets bearing half the characteristics of the father[20] so that the progeny will have the sum of these packets. If mother and father were closely alike this sum will then very closely approximate both parents. And when the parents were alike and their parents, to several generations, that is, when as we say they were homozygous, these little packets from mother and father are so much alike that they fall naturally into pairs and remain so until such a time as new eggs and sperm are to be formed. Throughout most of the life of the organism this pairing is rather loose, and if one sees two such packets quite separated, one is not disturbed. But just before new germ-cells are to be formed, the elements from father and mother seem to draw together into closer union before separating definitely to the daughter cells. This stage is what we call the synphase (syndesis), and if at this stage we find our little packets lying not in pairs but scattered, and if, as usually then happens, these packets are not distributed in even numbers to both daughters, we can be sure that something is wrong.

This is exactly what happened when I came to interrogate the banana under the microscope. If I took a piece from a root, or (though the roots are the easiest to work with) from the stem or leaf or flower body, and examined the nuclei I found thirty-two neat little black packets, some straight, some crooked, but always the same number. Now if the parentage of our banana had been quite proper and above board I should have found at syndesis sixteen neat pairs. But I did not find sixteen pairs. Instead there were only twelve pairs. The other eight packets were scattered, unattached, and when the daughter cells were formed, these eight were often not evenly distributed. At last I had found a question in the answering of which my banana had exposed itself and given me a glimpse into its past.



PHOTOMICROGRAPH OF THE CHROMOSOMES

FROM A ROOT TIP OF THE "CHEVALIER" BANANA, ONE CLOSELY RESEMBLING THE GROS MICHEL BUT HAVING THIRTY-SIX INSTEAD OF THIRTY-TWO CHROMOSOMES. THE MAGNIFICATION IS ABOUT 2,500 TIMES. PREPARATION BY THE AUTHOR.

There are several ways in which such a grouping of our little packets might have come about, but only one is backed up by more than the slimmest possibility, and it is that one that we shall consider. If a sperm containing twelve

[20] Because the phenomena here outlined are characteristic of both plants and animals I have borrowed the terms sometimes restricted to the animal field.

chromosomes were to fertilize an egg containing twenty chromosomes only twelve of the egg's chromosomes would find mates and there would be left over eight "old maids." So long as the social intercourse among chromosomes was general and the vegetative prosperity permitted a single unified community, they would behave quite normally, but when hard times forces the community to divide and those who can, choose mates (excuse my metaphors!) these eight would be left to wander aimlessly on the boundary between the two communities to fall at hazard into either one or the other.

I believe that some such thing happened here.

The banana has then told me a little concerning itself. It has told me that one of its parents gave it twelve chromosomes and the other twenty, though it has not told me which parent was which. But that does not matter so much in bisexual plants as it would in unisexual animals. Since each parent gives its offspring only half of its characteristics one parent must have had not twelve but twenty-four chromosomes while the other had not twenty but forty.

The conclusion is perhaps not obvious. We started with the supposition that it was necessary to use the Gros Michel as a parent, and its parthenocarpic sterility presented a seemingly insurmountable barrier. But now another possibility presents itself. The Gros Michel has hinted to us that perhaps, just perhaps, we can discover who its parents were. And if we can, and one of them is immune to Panama disease, why not breed them again, and produce a new immune Gros Michel? It is not, of course, certain that either or both parent varieties is now living, for much can happen in five or ten or twenty thousand years, but at least we can look.

It may surprise my readers to know that there are not less than, and probably more than four hundred named varieties of bananas from which to choose. That means something like 160,000 possible combinations—quite a formidable array. But let us not be discouraged. Let us delve a bit deeper to see if it will be possible to eliminate some of these four hundred. I have not been able to interrogate all of them, for many are still hidden in the jungles of India, Malaya, Burma, Siam, Cochin China, the East Indies and elsewhere. But, thanks to the United Fruit Company's extensive collection in Panama, I have studied some 150 of them, with again moderately encouraging results.

Out of them all one single variety, a native (?) of the Philippines, answered to the call of twelve chromosomes. This is not one of those we wanted unless under the influence of cold or some other untoward agency it might be induced to give not half but all its chromosomes to its progeny (this has been done in some apples and fireweeds). So we will not discharge the witness yet but relegate him temporarily to the bench. Nor did I find any with sixteen chromosomes, although Tischler found one such in East Africa (a descendant of one of Vasco da Gama's importations?). Of those with twenty chromosomes all but two are obviously "not guilty" for three of them are of the type of the Abyssinian banana, six are "hemp bananas," very different from any other group, and only two, one from New Guinea and one from the Philippines, are possible culprits, even under the unusual conditions suggested for the twelve types. But thirty-seven varieties answer to the number twenty-four, one of our potential culprits, twenty-one of them from the region of the Far East where bananas presumably took their origin: Java, Sumatra, Burma, Malacca, Siam, Farther India, etc. Many of them are much alike, but there are at least eight distinct species among them. These must be set aside as among the possible culprits. There were in our collection three more

with this number which we had ourselves created (hybrids), two with twenty-three chromosomes and three with twenty-two. Only a single wild variety, from Cuba, had twenty-eight chromosomes, but interestingly, one of our synthetic varieties, the progeny of a twenty-four and a thirty-two, had the same number, showing the possibility of such intermediate numbers arising by artificial methods.

And now we come to our thirty-two-chromosomed types, the first cousins, perhaps, of our Gros Michel. No less than fifty-nine varieties with this number appeared. Most of them, like the Gros Michel, are sterile and they represent most of the edible forms. Only a single one, "Ta Ni Pa" from Siam, often produces seed, and six others occasionally do. It seems probable that we can discharge all these as definitely not implicated. In the same way, although thirty-six varieties showed thirty-six chromosomes each, only two of them occasionally producing seed, many of them are quite indistinguishable from the Gros Michel. The implication is that one of their parents was the same as Big Michael's. At any rate, we can not accuse them of parenting him. I found no varieties with forty-four or forty-eight chromosomes and find the latter mentioned only by Tischler, who was unable to tell me anything more about his variety other than that it came from Java and bore a name which suggested that it might have come originally from India (Pisang Kladi).

"But you have not mentioned any which answer to the name of forty—one of those which you need as possible parents for your Gros Michel!" True, I have left those for the last. For I found them only at the last moments of my search. I had almost given up, almost ready to acknowledge that I might have been mistaken in his parentage, that perhaps the probable origin of that peculiar combination 12–20 was not the true one. And then, in the last dozen out of all those hundred and fifty witnesses to be interrogated, I found two (no, only one!) possible culprits. Two varieties showed forty chromosomes, so that my prediction made nearly a year before that such a one would be found was fulfilled. One of these was a variety from the Philippines, going under the alias of "Tiparot," and might be one of our culprits. But the other one was not a wild species but a synthetic one, a hybrid! And further wonders, we knew who its parents were! Its mother was an occasional seeding variety with thirty-two chromosomes. On the basis of our theories its father should have had forty-eight chromosomes. Yet we knew, or thought we knew, that there were no forty-eight-chromosomed types in all Panama! Could we have been mistaken? No. That other parent was a twenty-four-chromosomed banana of the "Basjoo" type. Through some anomaly such as we had envisioned as a possibility but not a probability for our twenty-chromosomed types, the father had given not half but all his chromosomes to his progeny! And this progeny was actually more viable, more fertile than either of its parents! It could not possibly have been a parent of the Gros Michel, since it was created at least a hundred and probably many thousands of years after the creation of the Gros Michel, yet it was excellent as a potential parent of such types! What could be a better demonstration of the potential feasibility of our original plan?

How many possible parents have we now to consider? Discarding all (1) sixteens, all (1) eighteens (I had put that among the twenties for reasons irrelevant here), all twenties of the Abyssinian and "hemp" types, all (6) twenty-twos and twenty-threes, all (59) thirty-twos, all (36) thirty-sixes, my one synthetic forty, all (1) forty-eights and all hybrids, we have left 38 twenty-fours, 2 twenties, 1 twelve and a single forty, a

total of not more than 138 possible combinations, instead of the 160,000 that we started with. True, there are some 250 more varieties that we have been unable to take into our survey, but even so it is doubtful if we should find enough new twenty-fours and forties to bring the combinations to a very unwieldy total.

Thus, where geology, archeology, history and ethnology have failed to burrow under our second wall, by planting our banana itself thereon we have sundered it. Now the problem must pass from my hands, as a cytologist, to others; to the plant explorer to search out in the jungles all other types of bananas to be included in our survey; and to the plant breeder, to take these possible parents and test out their progeny, to see now whether it will be experimentally possible really to combine fruit characters, productivity, immunity to disease and seedlessness, in a single super-banana. And our third wall now appears far less formidable than it did at first, for we see that in trying from seed-producing varieties to produce seedless ones we are only attempting what one group of animal breeders does constantly, namely, the mule breeder. Taking choice mares and asses, fertile, he produces a hybrid progeny which is always sterile. So long as we thought of the Gros Michel itself as the important race, the double reversal of sterility-fertility-sterility seemed our only recourse, and a very difficult one. But, looking at our Gros Michel now as a hybrid and its parents as the important things, we can face the dilemma with equanimity since it melts into thin air. We do not have to reverse our initial sterility since it does not exist in the parent and we have good reason to expect a sterile progeny. Perhaps we shall conquer our disease yet. Surely it is worth trying!

At the risk of appearing anticlimactic I am going to present another aspect arising from this study, that of genealogy and of evolution in general. You will notice that in the figures I have given, out of 150 varieties only eight have numbers which are not multiples of four. These were eighteen (1), twenty-two (4), twenty-three (2) and thirty-four (1), and of these 1 twenty-two and 1 twenty-three were known to be hybrids. This gives us some insight into how the whole race of bananas may have evolved.

It is a well-established rule that the basic number for such a polyploid series, as we call it, must be not more than twice the highest common divisor of the species numbers (known or unknown, of course, since it must include extinct species as well as existent ones). Now throwing aside these eight as being obviously aberrant, we may take eight as our basic number. I might expect to have found such a one, but since the race with which we are dealing began with that number at least a million and a half years ago and probably much more, it does not disturb me much to have failed in my search so far. Perhaps it still does exist in the jungles of Malaya. As we have demonstrated experimentally in synthesizing our forty type, it is possible for a sperm or egg, under some conditions, to carry with it not the usual half number of chromosomes but the whole number. Now that half number (starting with eight as our first whole number) is four and the whole number is eight. Their sum is twelve. This number we find in one of my specimens from the Philippines. If both egg and sperm bore not the half but the whole number the sum would be sixteen, as we actually find it in Tischler's East African variety, "Dole." I could, of course, now cross my twelve and sixteen to get eighteen, but I prefer not to for many reasons, chief of which is that I have found only one eighteen and that obviously derived in another way. But let us continue our doubling process for a little while. In the case of "Dole" we are perhaps justi-

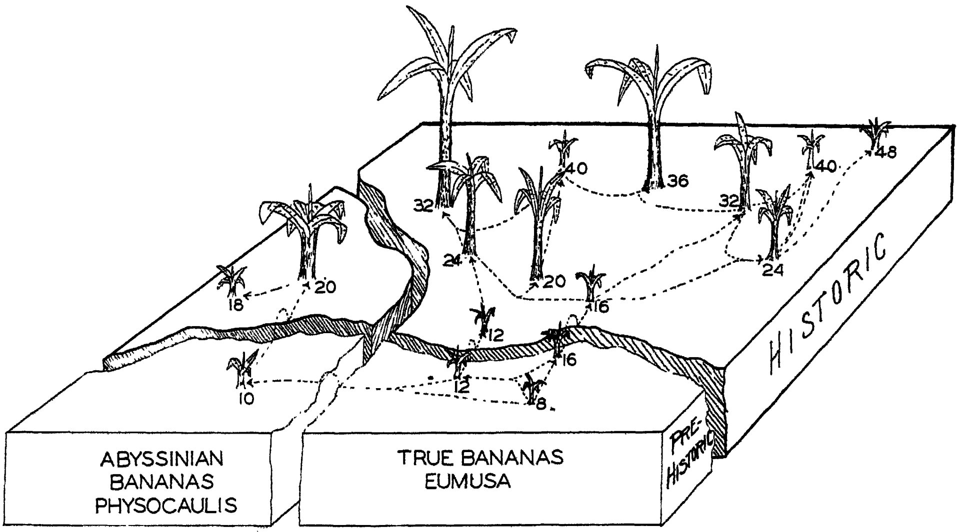


DIAGRAM ILLUSTRATING THE POSSIBLE INTERRELATIONSHIPS OF THE VARIOUS GROUPS OF BANANAS. THE SIZE OF THE PLANT IN EACH CASE REPRESENTS THE RELATIVE FREQUENCY OF OCCURRENCE OF THE CHROMOSOMES GROUP TO WHICH IT BELONGS.

fied in doing this (or rather assuming that it has been done) by our supposition that it had just completed one doubling under extraordinary conditions. In the case of our "Philippine unidentified" (as it is designated in my records) we are even more justified by the well-known fact that a heterozygous hybrid often makes itself homozygous by the simple expedient of splitting all its chromosomes in two (or perhaps separating them and bringing them together again by uncompleted cell division) thus creating its own pairs. We should then get a fertile thirty-two (which we have in our single representative "Ta Ni Pa") and a fertile twenty-four which is represented by our large "Basjoo" group (one of our probable parents for Gros Michel, you will remember). Now cross "Basjoo" (twenty-four) and "Dole" (sixteen) and we have twenty, representing our hemp (textilis) group which doubles to form one forty type, "Tiparot." Cross "Basjoo" (twenty-four) and "Ta Ni Pa" (thirty-two) and we have twenty-eight, our single "Dorado," a poor, sterile, useless hybrid (the odd-numbered multiples are usually poor) which could not even double itself further and would probably have been doomed to extinction in the mills of natural selection, had it not been for us prying botanists. Cross "Ta Ni Pa" (thirty-two) with "Dole" (sixteen) and we have another twenty-four type, possibly "Lady Finger," which being an even-multipled hybrid doubles to form a forty-eight "Kladi." We have already crossed one thirty-two type (in that case "Apple Plantin") with a twenty-four type, "Bastard Hemp" (probably a "Basjoo") to get our anomalous synthetic forty, instead of the expected twenty-eight. And we have supposed this forty to have crossed with a twenty-four to produce "Gros Michel" (thirty-two) and with a thirty-two to have produced "Pisang Sri" (thirty-six). And here again we have incidental evidence of the validity of our suppositions, for we see now why, perhaps, "Pisang Sri" and "Gros Michel" are so much alike, for both have exactly the same grandparents and one parent of the two is the same. No wonder they

are alike! We might theoretically carry on this doubling and hybridizing to infinity, but as I have said, odd-numbered multiples and, even more, fractional multiples (22, 23, 34), have a very low survival value. Moreover, as we mount our tree the numbers increase, the balance of characters becomes more delicate and hence the high numbers are less likely to survive. And perhaps, also, two million years is not long enough for higher numbers to have had time to evolve!

But what of our Abyssinian banana? Probably somewhere back in pre-Tertiary times a twelve type crossed with our ancestral eight, giving ten, and this then doubled to form the twenty of the Abyssinian. This is quite a different origin from the "textilis" twenties and much more ancient. And this in turn lost two of its chromosomes to form our single eighteen. Perhaps Professor Muller's cosmic or earth rays caused these chromosomes to fuse sometime in their bearer's travels between Colombia and Abyssinia (we can not say in which place, if either, they originated). At any rate we now have a pretty complete though admittedly hypothetical genealogical tree.

We have shown, then, a method by which the problem of disease control may be attacked by one who is not a pathologist. And we have broached another even more fundamental problem. In a recent issue of this journal there appeared a paper by Professor H. J. Muller entitled "The Method of Evolution."[21] I should prefer that he had entitled it "A Method of Evolution," for though the evidence of the existence of mutations is unquestionable and the evidence for the activity of cosmic and earth rays in producing these mutations grows from day to day so that I should certainly not concur with Professor Jeffrey in ridiculing this method, I nevertheless feel that the evidence for concomitant evolution by hybridization is even better established, and that, while perhaps it is not so fundamental in scope as is the "ray" evolution, it has played a much more obvious and far-reaching rôle than has the former. This polyploid genealogy is not an isolated example but is typical of whole family groups and also occurs (perhaps of a different origin?) in Professor Muller's own fruit-flies. But I do not wish to be drawn into any controversy over the methods of evolution, so I will leave it to my readers to judge of the validity of my conclusions.

21 H. J. Muller, "The Method of Evolution," Scientific Monthly, 29: 481–505, December, 1929.

THE TREE THAT DOES NOT YIELD A PROFIT

By W. W. ASHE

U. S. FOREST SERVICE

UPON the tomb which marks the grave of a Bishop of Chichester there is said to be this inscription, "I shall come this way but once," and this seems to be the point of view of many who have cut trees into lumber, that they shall never return for a second cutting, or to see the outcome of their labors. As a result of this outlook there are in the United States, according to estimates of the U. S. Forest Service, about eighty-five million acres of land that might be producing timber but instead are standing idle. This area of idle land is about twice the size of the State of Virginia.

This problem of our devastated and idle cut-over woodland has been intimately associated with another problem, "The tree that does not yield a profit." It has been the general policy of sawmill men to cut every tree above sapling size, to cut clean, as they say. This method was often followed because they were unable to decide as to what size it was not profitable to cut, often because, having purchased and paid for the timber, they were apprehensive lest profitable material would be left for which they had paid. There has been justification, however, for this dilemma.

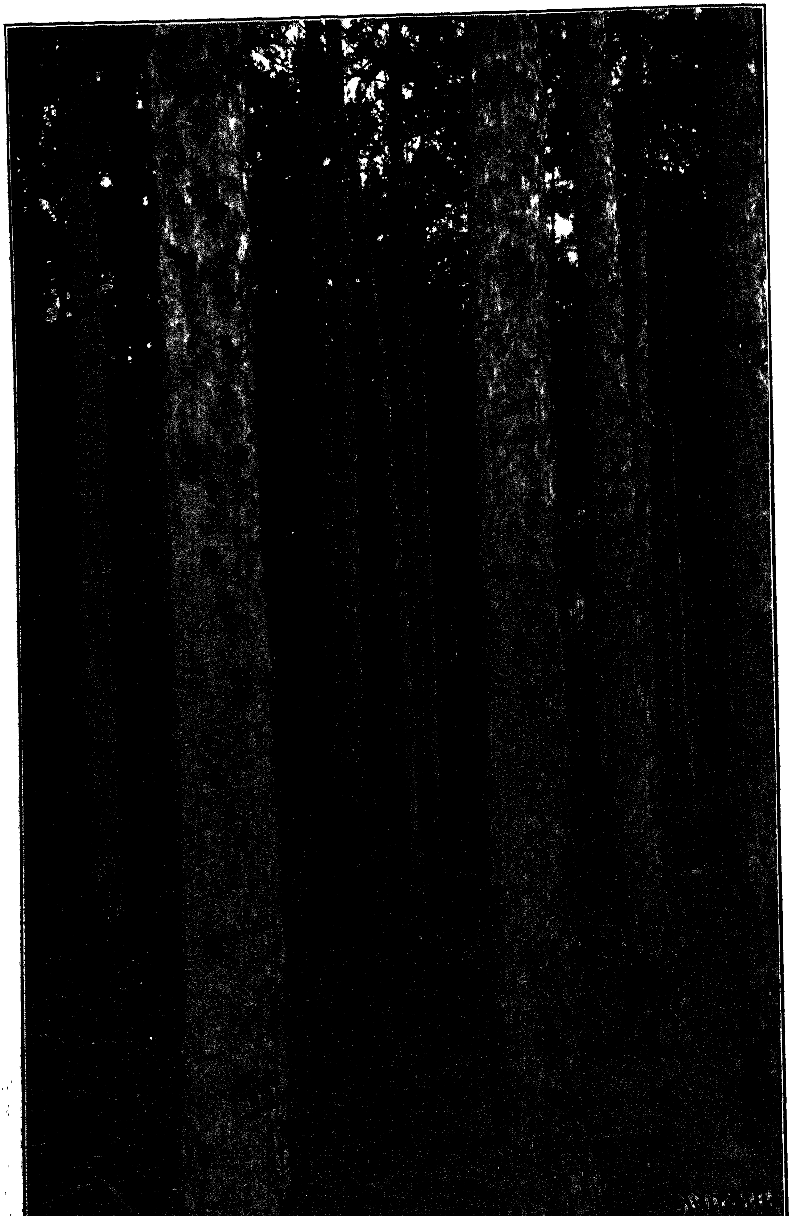
Few problems in industrial engineering have been more perplexing than the determination of the size of the tree which it pays to cut and the relative profits which can be made from cutting and manufacturing into lumber trees of different sizes. As a result of this ignorance millions of small trees have been yearly sacrificed, contributing only a loss to those that cut them.

This problem of the unprofitable tree has been perplexing to those engaged in selling trees and one equally as perplexing to those manufacturing trees into lumber. It has been a serious problem to the large as well as the small sawmill operator. Does it pay best to take out all trees for sawlogs or if it pays to leave trees, trees of what size, and how many? The sawmill owner's interest in and his consideration of this problem is primarily not from the point of view of what is best for the land, but rather entirely from the point of view of the profits and relative profits in turning sound trees into salable lumber—of liquidating his investment in timber.

Methods have been worked out for solving this problem—solving it satisfactorily even to skeptical mill managers and superintendents and to quizzical boards of directors—and by solving it thus taking certain elements of cost keeping in the lumber industry out of the category of empiricism. This crepuscular zone of trees of doubtful profit can now be fully illuminated.

Investigations conducted at different classes of mills, large mills as well as small mills, and made in different states in widely separated regions have clearly demonstrated that a large portion of the small trees above sapling size which are at present being turned into lumber are being converted at a loss or at best merely at a nominal profit. That is, there are marginal and submarginal trees just as there are marginal and submarginal agricultural lands—lands which can not be cultivated at a profit—trees which can not be cut at a profit, though standing cheek by jowl with larger trees that are profitable.

Each sawmill operation has its own



—*Photo by W. W. Ashe*

A STAND OF RED PINE IN MICHIGAN

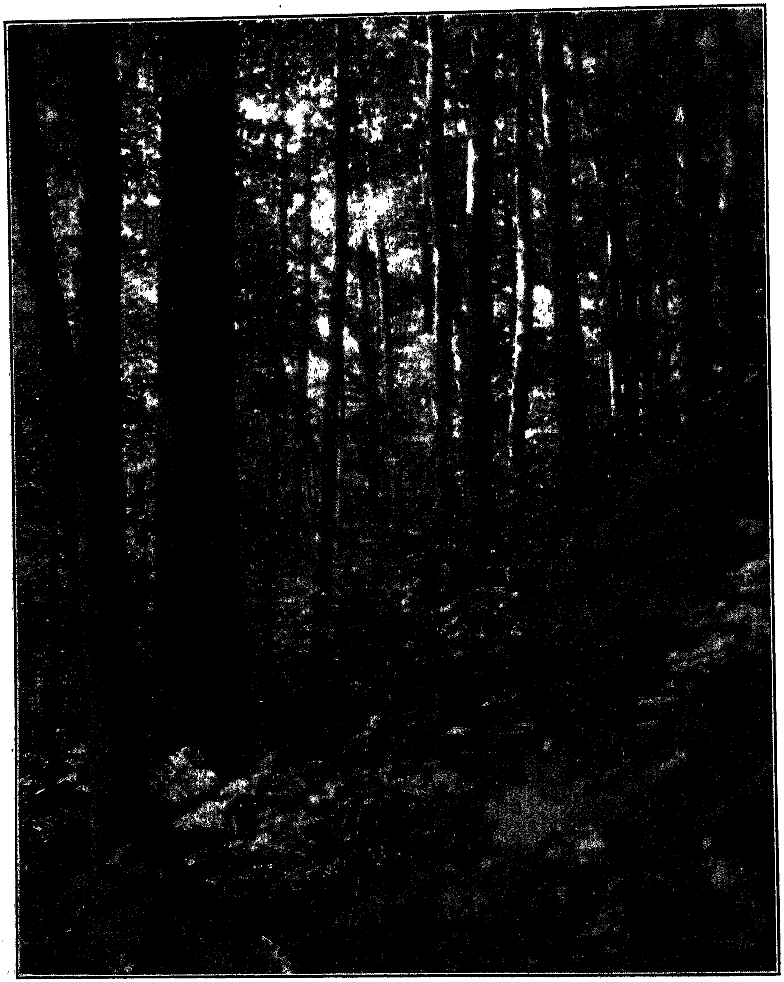
WHICH PROBABLY WILL BE CUT CLEAN AND ITS INVESTMENT VALUE DESTROYED OR MATERIALLY IMPAIRED. NO INFORMATION IS AVAILABLE AS TO THE SIZES TO WHICH TO CUT WHITE OR RED PINES TO SECURE MAXIMUM PROFITS.

diameter of maximum profits, and the figures which are secured at one operation consequently may not be applicable to another. While this is the case, there is within a given region and for a designated kind of timber a comparatively narrow range of variation. The results of these investigations may thus be standardized by regions and by kinds of trees.

The difference in the cost of operating large and small trees results from several factors. One is that far more weight of wood must be handled in producing a foot of lumber from logs which are cut from small trees than in producing a foot of lumber from logs from large trees. So long as the wood is in the log, the weight of the bark must be considered and added, since the bark is a part of the log through all its handlings until its journey as a log ends upon the saw carriage, where the log is sawed into boards. Since more weight must be handled, more labor and a longer time are required. The difference in the weight of wood which must be handled is roughly indicated by the number of square feet of board which can be sawed from a cubic foot of solid wood. Only 2.5 square feet of such lumber can be manufactured from a cubic foot of wood in trees eight inches in diameter, but 5.4 feet of boards can be produced from logs taken from trees which are sixteen inches in diameter. Logs from trees twenty-four inches in diameter, however, yield 6.8 board feet to each cubic foot of solid wood. That is, there is a far larger proportion of wood lost in the form of sawdust, slabs, edgings and trimmings in sawing up the smaller trees.

Neglecting the difference which results from the variation in the proportion of bark it may be said three times the weight of logs must be handled in moving eight-inch trees that is handled in moving twenty-four-inch trees through the different logging processes necessary to produce a thousand feet of boards. This carries the log up to the time when the boards drop from the teeth of the saw. Not only must more cubic feet of wood be handled but also more trees and more logs. Seventy-eight logs cut from eight-inch trees are needed to produce a thousand feet of boards, but only one and one quarter logs are needed from a tree twenty-four inches in diameter to produce an equal quantity. But the difference in time and labor is not confined to the handling of logs and to the different steps which involve merely the handling of logs. Even after the logs are sawed into lumber the evil dryad which resides in the smaller trees still follows the lumber made from them. If the trees of different size are considered on the basis of the number of pieces of board which are sawed from them in place of the weight or number of logs there is still a most unfavorable showing for the small trees. When these smaller 78 logs are manufactured into lumber they produce 240 separate and distinct pieces of board. The twenty-four-inch trees, however, saw out only 114 pieces of board to the thousand feet. That is, more than twice as many pieces of board are manufactured from the small trees as from the large trees, but unfortunately these boards from the small trees are of narrow width and often of shorter length. It requires, however, as the investigations have shown, essentially as much time for a laborer or a machine to handle a narrow board as a wide one.

Suppose these differences in the number of trees to be felled for making a thousand feet of lumber, in the number of logs which must be sawed up, in the number of pieces of lumber which must be handled, are translated into relative time or costs of handling. Costs, however, will not vary exactly in the same proportion as the number of pieces of



—*Photo by W. W. Ashe*

A STAND OF HARDWOODS

IN THE MOUNTAINS OF NEW ENGLAND, WHICH ON ACCOUNT OF THE LARGE PROPORTION OF SLENDER TREES OFFERS AN EXCELLENT OPPORTUNITY FOR THE APPLICATION OF THE PRINCIPLE OF CUTTING FOR MAXIMUM PROFITS.

lumber, as the number of logs or as the weight of logs. Exact costs for handling trees of different sizes have been secured by timing each step in the logging woods and in the sawmill operation. This timing began at the stage when the tree was notched, that is, when the little chip was taken out of its base which determines the direction in which the tree will fall. The stop watch followed the felling of the tree and kept the time through the different steps to the final act of all, when the lumberman bade good-by to his product and the finished lumber ready for use was loaded in cars for shipment to the distributing yards in towns and cities.

Such investigations have been conducted at a number of plants, among others at that of the Crossett Lumber Company, which manufactures at its Arkansas yellow-pine mills more than forty million board feet of lumber a year. The figures secured at this and at other plants as a result of these investigations have been averaged. They show that during the time required to fell and to cut into logs enough eight-inch trees to produce 1,000 feet of boards enough logs can be cut from twenty-four-inch trees to produce 2,500 feet. For this activity it is two and a half times as costly to handle eight-inch trees as twenty-four-inch trees. The actual cost of this and other activities will vary in different parts of the country as wages vary, but the relative costs for trees of different sizes at any specified operation will vary essentially as does the relative time which has been determined for this activity.

Another important step is sawing the logs into boards. It costs at a supposedly efficient band sawmill operation in Alabama more than $9 a thousand feet to convert into lumber the logs which are cut from trees eight inches in diameter. At the same mill it costs less than $2 to saw an equal amount of lumber from logs taken from trees twenty-four inches in diameter. For sawing one thousand feet of boards at this sawmill the ratio of cost is four and a half times as much in the case of the smaller trees as for those of larger size. Nevertheless, this ratio is not exceptionally high for mills of this class which are primarily for handling logs of large size rather than very small ones. Notwithstanding the relatively higher cost of handling such small timber, many trees of this size were daily felled, hauled to the mill and sawed up. The low cost and the profits made in handling the large timber absorbed the high cost and the resultant loss in converting the small timber, and no one was the wiser. It is a proverbial case where ignorance is bliss.

In a circular sawmill the respective costs for sawing one thousand feet of boards were $4.50 and $1.20. The ratio of cost is still nearly four to one. It must be understood that the ordinary portable circular sawmill is designed primarily for handling logs of medium size, and while this mill showed somewhat greater efficiency in sawing up very small logs than in sawing up those from trees as large as twenty-four inches in diameter, there was a rapid decline in its efficiency in handling logs of a very large size.

Felling and sawing into boards are by no means the only steps in a sawmill operation, but to the casual observer they stand out as the important processes. In an ordinary lumbering and sawmill operation involving a large-sized unit, making use of the type of mill known as a band saw and necessitating a logging railroad to bring the timber from the woods to the mill, there are twenty distinct activities or divisions of cost. The costs of some of these activities are not affected by the size of the tree. Some are influenced by the total amount of timber which is cut.

The total cost of the sawmill or railroad is the same regardless of the size of the trees or the amount of timber. The larger the aggregate amount of timber which can be cut or which is available for transportation the smaller is the amount which must be charged against each thousand feet of timber for erecting the mill and for building the railroad. These items are known as construction costs or construction overhead costs. Likewise, there are some items of cost like drying which are essentially constant, regardless of the amount of timber which is cut or the size of the trees from which the lumber is manufactured. The average sawmill operator as a rule claims that after a mill has been placed, after the railroad has been constructed or a road graded or improved, it is more economical to cut the smaller trees than to leave them. In case the timber has been purchased at a lump sum this is a further incentive to cut clean. Frequently this "pound of flesh" is taken at a dear cost.

After making a full allowance for the increase in the cost of manufacture, because of distributing the construction costs over a reduced cut of lumber, it has been clearly shown at the operations investigated that even the trees of what might be called medium size are being cut at a loss. Other trees are cut which yield only the scantiest profit, too little in fact to make a satisfactory return on the investment. This is particularly so in the eastern states in the operation of the class of timber known as second growth in which close cutting is the prevailing practice.

The plants at which these investigations have been conducted are typical plants, cutting typical stands of timber. The conditions at these mills can be duplicated at many others. The stands of timber were quite similar to many stands which farmers sell to sawmill men or which they themselves cut.

So far only operating costs have been considered. These investigations likewise show that a thousand feet of boards sawed from large trees have a far higher selling price than the same amount of lumber sawed out of smaller trees. The comparative values of the lumber of southern shortleaf pine are available. The graded lumber sawed from such trees eight inches in diameter has a mill value of less than $13 per 1,000 board feet. The lumber from such trees sixteen inches in diameter has a value of about $20.50 per 1,000 board feet. That from twenty-four-inch trees has a still higher value, $23.50 per 1,000 feet, or nearly twice that of the lumber from the eight-inch trees. At the same time it costs nearly three times as much to manufacture the lumber from these small trees. It is this combination of increasing costs and decreasing value as the size of the tree becomes smaller that secures the attention of the operator.

When the selling price of lumber and the cost of manufacture were compared it was found in an investigation made in a large operation in southern Arkansas, with large investment in sawmill plant and railroad, that the highest profits were being made by cutting no tree below sixteen inches in diameter. To cut to this diameter reduced, of course, the total amount of lumber made. This reduced cut, however, was more than offset by the increase in the price of lumber as a result of eliminating the large proportion of low grades in the smaller trees and the higher cost of handling them. In a portable sawmill operation investigated in Alabama the greatest profits per 1,000 board feet were realized by cutting no trees below eighteen inches in diameter.

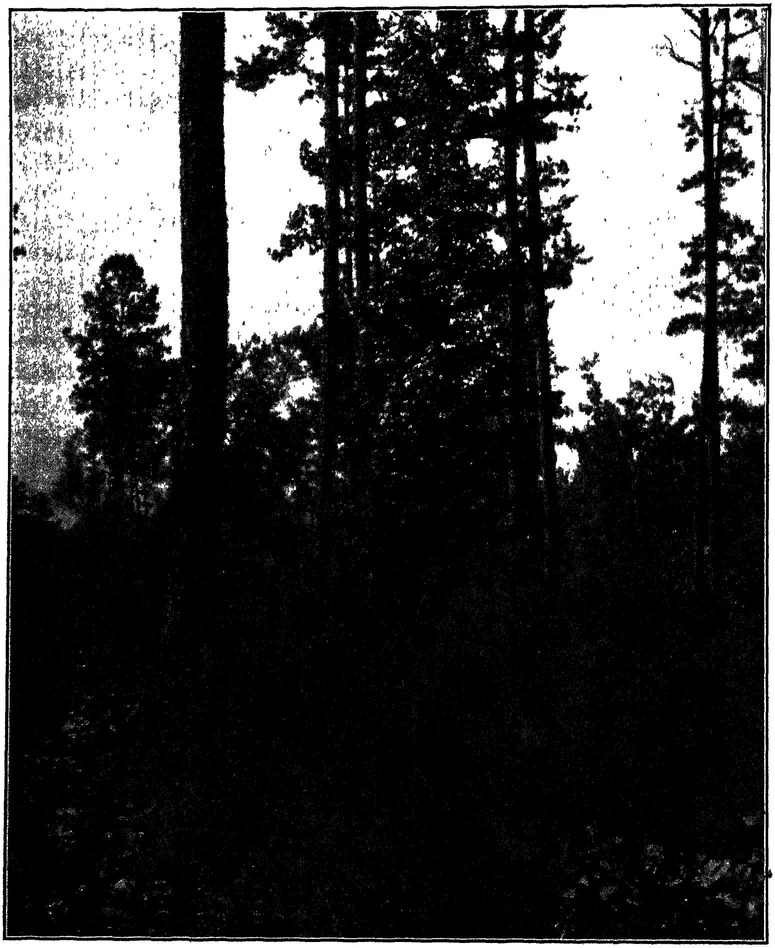
This problem so far has been considered entirely from the point of view of the sawmill man. Even when he cuts to secure the maximum profits, in most cases a large number of medium-sized

trees will inevitably be left. Some large concerns like the Crossett Lumber Company, for whom investigations of this kind have been conducted, are cutting very conservatively. This company's acute cut-over land problem is a problem of unproductive lands that were closely cut over before it adopted its present cutting policy. These lands amount to many thousands of acres out of a total of about 500,000 acres owned in Louisiana and Arkansas. The difficulty with which the company is confronted in rehabilitating these devastated lands has been overcome to a great extent in the case of lands which it has cut over more recently through the adoption of these scientific cutting methods. These methods were based upon a thorough analysis of the costs of the operation. This analysis showed that by observing a higher diameter limit in cutting the mill would secure a higher aggregate profit from its entire operation than if it continued to cut to a smaller size or even to cut clean.

The Crossett Company, and such other concerns as have adopted a similar cutting policy, are securing the highest profits from their operation. They are cutting no trees which a complete analysis of their operation has shown to be unprofitable. This policy has been extended by some companies so as to leave many trees which could be operated at only a nominal profit. The result is that such concerns can look forward to a profitable recutting of lands at an early date. This second cutting in some cases will have the benefit of trees nearly as large as those in the natural virgin stand and will yield a large proportion of the high and valuable grades of lumber. It will have low logging costs and often will result in conditions which will permit the operation to be continued indefinitely.

A further and likewise an important aspect of this problem is the influence which the failure to cut these small trees if adopted as a general practice would have upon the lumber industry itself. Few private investors will consider waiting sixty or even forty years for growing a crop of saw timber from the seed without assurance of profitable intermediate returns. Leaving these trees of the size of telephone poles or somewhat larger will go far towards perpetuating the lumber industry on its present industrial foundation, through furnishing in the early future the timber of sufficient size to produce the customary proportion of grades of lumber for which the American market calls.

Likewise, through the general use by land owners of the conclusions from these investigations it may be possible to avert for at least a portion of the remaining uncut forest lands the overwhelming disaster which has overtaken the more than eighty-five million acres already unproductive chiefly as a result of too close cutting in the past. As a rule, such of our pine lands as are in private ownership are still being cut clean or nearly so. It is true that a few small trees of around sapling size are being left, but only a few owners as yet require that larger trees of the size of telephone poles and larger shall remain uncut. Trees of this class would within a year or two furnish seed for restocking and, more important, by their added growth they might in a few years more supply material for a recutting. The fact that these pole-sized trees can be converted into lumber at only a nominal profit at best at once presents the most important reason for not cutting them. If they are left, and the owner of the land realizes the possibility of an early second cut, there is an incentive for him to protect his land, to care for it as an investment. This is one, and perhaps it is the most important, of the public relations aspects of the problem of the small trees. Had this system of cutting been



—*Photo by W. W. Ashe*

GROUP OF SHORTLEAF PINE-TREES

IN ARKANSAS THREE YEARS AFTER CONSERVATIVE LUMBERING UNDER MAXIMUM PROFITS PRINCIPLES. THESE TREES COULD HAVE BEEN REMOVED ONLY AT A LOSS, YET A FEW YEARS BEFORE ALL SUCH TREES WERE BEING CUT IN THIS OPERATION. AS THE RESULT OF ENORMOUSLY ACCELERATED GROWTH FOLLOWING ISOLATION THESE TREES IN LESS THAN TWENTY YEARS WILL FURNISH A PROFITABLE SECOND CUT. AS MANY AS TWENTY SUCH TREES ARE BEING LEFT PER ACRE.

applied in former years the area of waste land would not be nearly so large.

These waste lands are yielding their owners no income, and there is no possibility of income from them for many years to come. They are lands in which the owners have largely lost interest as active investments; lands which the owners hope to sell, to pass on to some one, perhaps to subdivide and retail for farming purposes; lands that lack any element of present value characterizing a fair investment or any hope of early and constant returns even at a low rate of interest. State and county, moreover, lose revenue from such lands, for on the whole in the long run they yield but little in the way of taxes. Fortunately, the eighty-five million acres are scattered among many states. The burden of carrying them, for it does impose the burden of extra taxes upon other property, is therefore somewhat distributed, though it falls as a rule upon the poorer and less able communities. Owners of large areas of such lands, particularly in Michigan, Wisconsin and Minnesota, have in fact given them up rather than continue to pay taxes. In Michigan alone more than 700,000 acres have reverted to the state.

The unfortunate situation is that the area of such land is increasing, increasing at the rate of more than a million acres a year as timber lands continue to be cut without due regard for their future earning powers, without an attempt being made to preserve their investmental value.

In the past sawmill communities have been ephemeral. On account of this the employees have been at a disadvantage as compared with those in other industries where continuity of employment was assured. Since the life of the mill operation was limited, buildings were often of poor construction and living conditions below the general prevailing standard. School facilities are still often inadequate. It was necessary in the limited operation that the entire investment in buildings and in mill plant be paid for out of the original stand of timber. If most sawmill operations, as seems possible as a result of these investigations, can be placed upon a continuous basis, the sawmill becomes a permanent wood-using industry. It becomes a fixed asset of the community. It should never be cut out. The complete payment for the plant and buildings need not be charged off against the cut of timber during a limited time, but merely repairs and upkeep and a nominal yearly amortization charge. It means, moreover, sustained public revenue for the counties in the way of taxes.

This is the most desirable situation which could possibly develop in the American sawmilling industry. The result of the general adoption of such plans eliminates the possibility of any great additional increase in the area of waste forest land, particularly in the eastern, southern and lake states. It places the concerns that make use of this principle in a most enviable position as forest land owners. The large old growth timber of the East is nearly cut out; the mills that carry forward these slender trees to become large-sized timber can look forward to producing quality lumber at low cost. Such mills as will be exclusively dependent upon young second growth stands containing only trees of small size must be content with knotty logs and with high cost of production.

HYDRAULIC LABORATORY RESEARCH AT THE STATE UNIVERSITY OF IOWA

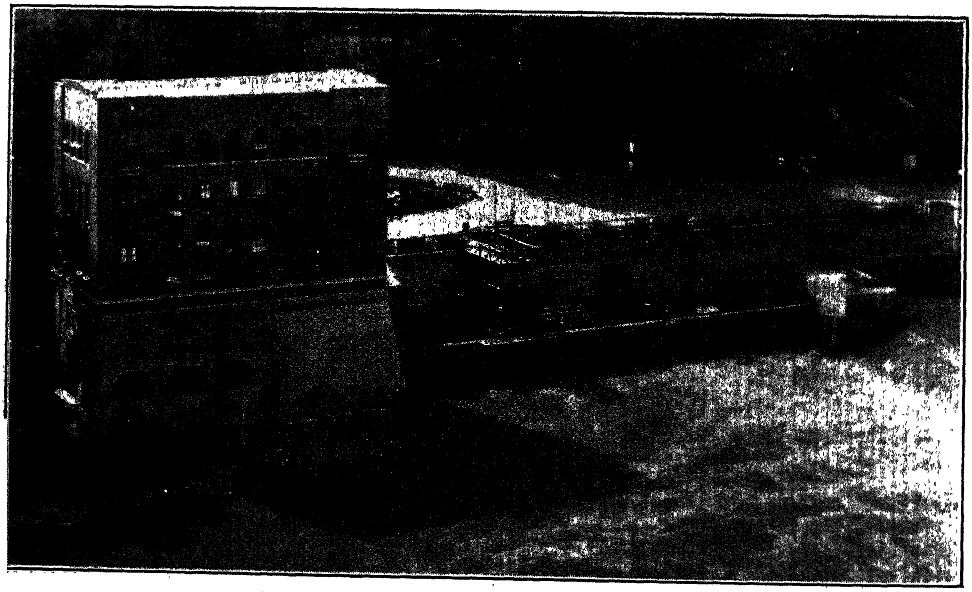
By Professor SHERMAN M. WOODWARD

HEAD OF THE DEPARTMENT OF MECHANICS AND HYDRAULICS, COLLEGE OF ENGINEERING, THE STATE UNIVERSITY OF IOWA

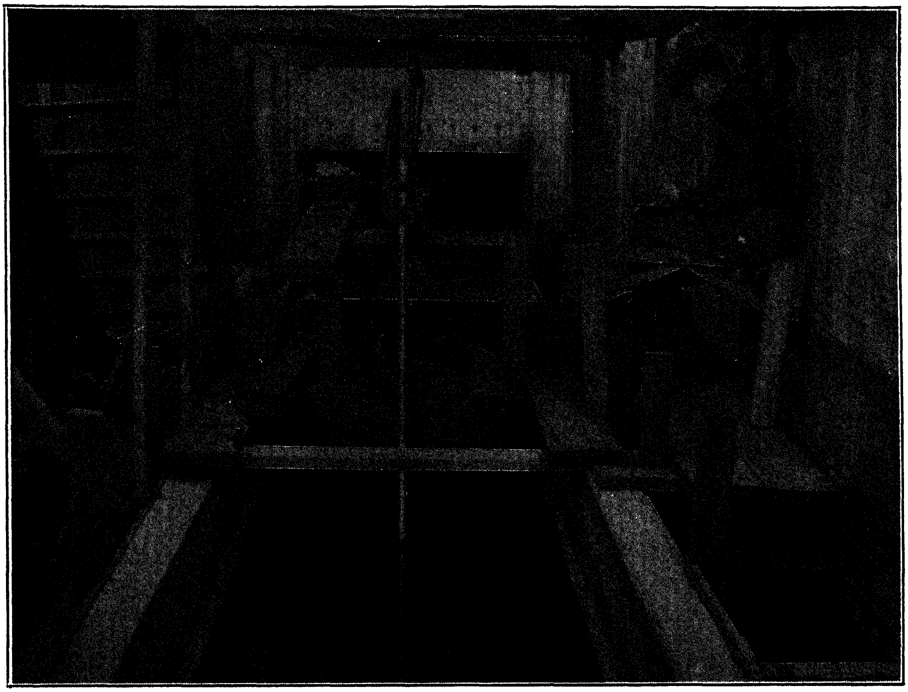
INTEREST in hydraulic experimentation has increased remarkably during the last few years. This development has been stimulated by the efforts of the engineering profession to persuade Congress to establish a national hydraulic laboratory, and doubtless largely also by the publication by the American Society of Mechanical Engineers of the monumental volume compiled by John R. Freeman entitled "Hydraulic Laboratory Practice," devoted chiefly to a description of the work of the numerous hydraulic laboratories in Europe.

Iowa University, because of its picturesque location on both banks of the Iowa River, a stream three hundred feet wide with an average flow of over one thousand cubic feet per second, is in a peculiarly advantageous position to undertake the experimental solution of a great variety of hydraulic problems. Through the generosity of a friendly donor, the university owns the water-power produced by a dam, nine feet high, across the river in front of the campus.

At the east end of the dam is a hydro-electric plant, which may be used when desired for experimental purposes but which is ordinarily used to furnish power for general university use. At the west end of the dam is a research hydraulic laboratory arranged so that as large a flow of running water as may be needed in experimental investigations may be used, up to the whole flow of the river.



HYDRAULIC LABORATORY AT IOWA UNIVERSITY



STUDYING THE EFFECT OF TURBULENCE
ON THE REGISTRATION OF CURRENT METERS.

The advantage of having available such a large supply of running water without the necessity of pumping it is of tremendous practical assistance in performing large-scale experiments. The head under which this large stream can be used is, of course, limited to the height of the dam. For experiments requiring a higher head it is necessary to pump the water used.

The hydraulic laboratory includes two main features. First, a straight concrete canal, ten feet wide and ten feet deep, about two hundred feet long, located along the river bank parallel to the thread of the river. This canal receives its water-supply through a large head gate in the end of the dam, and discharges its waters back into the river at its lower end.

Second, over the lower end of the canal, a building sixty feet long, thirty feet wide and four stories high. In this building are located offices, pumps, tanks, scales, piping and miscellaneous experimental equipment.

The growing demand for river improvements for flood protection, water storage, navigation, irrigation and water-power, coupled with the rapid evolution of various types of hydraulic machinery, has produced so many problems requiring laboratory research for their solution that the recently enlarged hydraulic laboratory at Iowa University has not been able to satisfy all the requests for the use of its unique facilities in this line. Some of the more important of the investigations that have been undertaken will be described briefly.

Flow Through Culverts

An elaborate series of measurements of flow through pipe culverts up to thirty-six inches in diameter and through box culverts up to four feet by

METHODS OF PREVENTING EROSION BELOW DAMS
MODEL OF A DAM WITH APRON.

MODEL OF A SECTION OF THE DES MOINES RIVER AT OTTUMWA, IOWA
LOOKING UP STREAM.

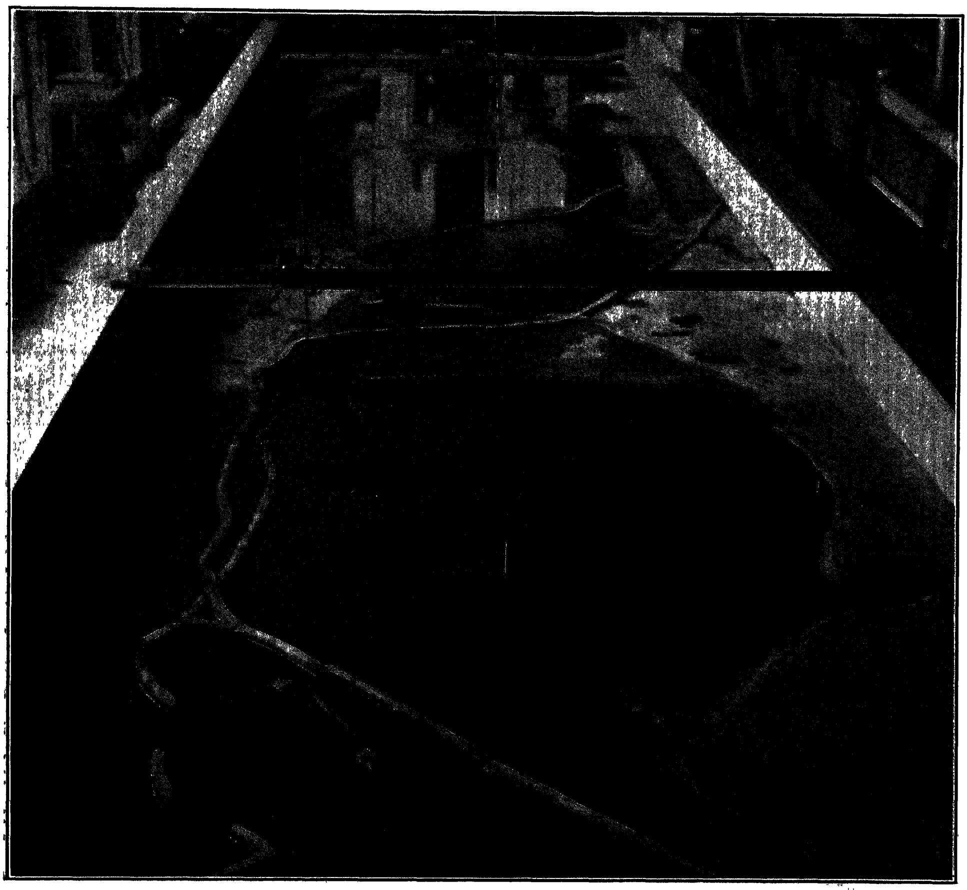
four feet in cross section was carried out for the U. S. Bureau of Public Roads by D. L. Yarnell. Friction losses for culverts made of corrugated iron, vitrified clay and concrete were determined, and the discharging capacities of culverts of different sizes were determined for various conditions. The results of these tests are now being used by highway engineers in developing improved highways all over this country.

Effect of Turbulence on the Registration of Current Meters

Current meters are so universally used in stream gauging that there has been much discussion of their accuracy under the variable conditions encountered in practical use. In this investigation a number of meters of different types were observed under controlled conditions simulating abnormal situations that sometimes occur. It was established that different types of meter evince entirely distinct tendencies to error in registration under such conditions.

Flow Around Bends

Most of the difficulties encountered by the hydraulic engineer arise from the fact that water must be made to flow along curved paths. An elaborate series of experiments was undertaken to deter-



THE FLOOD OF JUNE 1, 1903

One hundred thousand cubic feet per second, reproduced on model of Des Moines River without cut-offs.

MODEL OF THE DES MOINES RIVER WITHOUT CUT-OFFS
LOOKING DOWN STREAM.

mine the changes that take place in a stream of water having a constant cross section when flowing around a 180-degree bend. The pressure and velocity of the water were found to vary at different points to a surprising degree, and these changes follow definite laws, a knowledge of which can be applied usefully in a great variety of hydraulic machines and structures.

The Hydraulic Jump

Numerous experiments have been made on the hydraulic jump, both when stationary and moving, and in channels of various shapes.

Hydraulic Conditions at a Free Outlet

When water is discharged from a pipe, flowing full, into the air with a free fall at the outlet, rather surprising changes take place in the pressure and velocity distribution within the pipe close to the outlet end. Numerous experiments have been carried out to determine the laws that apply to these phenomena.

Weir Experiments

Various questions have been studied relating to factors determining or modifying weir coefficients.

Backwater Suppressors or Head Increasers

Whenever a flood occurs on a stream, all the water-power plants suffer from a loss of head at the plant. In low head plants this is often so serious as to cause

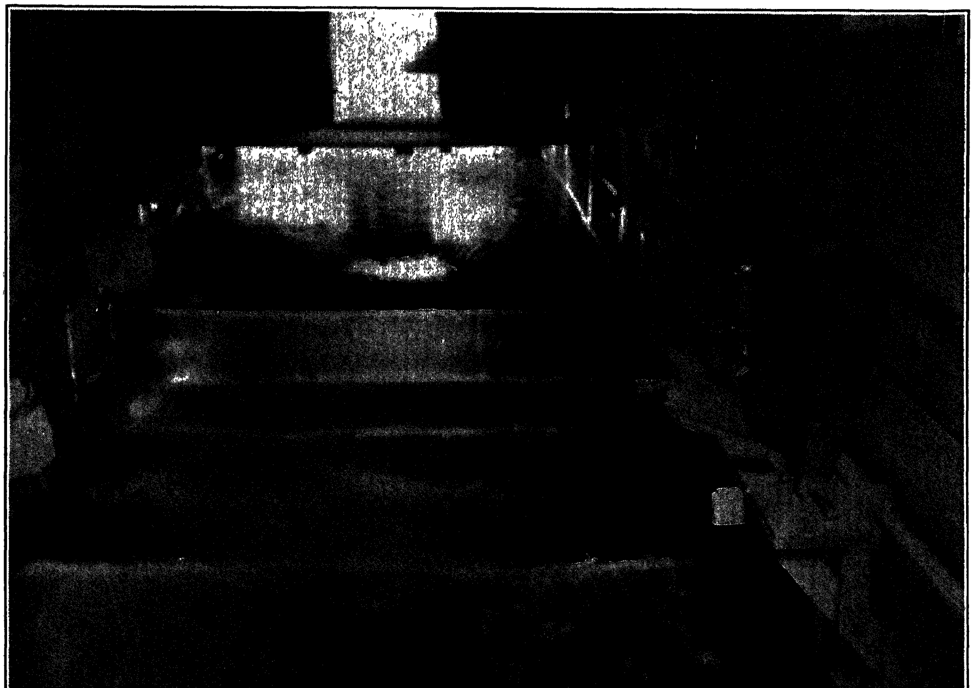
the plant to shut down during the continuance of the flood. Experiments have been made on various suggested methods and devices for turning the flood flow into a help to the power plant instead of a harm.

Calibration of the Keokuk Spillways

In times of flood in the Mississippi River, the amount of the flow is estimated by using the spillway gates on the dam across the river at Keokuk, Iowa. These gates are of so large a size that no similar openings had ever before been carefully rated. In cooperation with the Mississippi River Power Company the discharge through the spillway openings was carefully measured, after which a small model one eleventh the size of the spillways was constructed in the hydraulic laboratory. It was found that the flow through the model corresponded as closely as could be measured with the flow through the full-sized structure. This proves the great value of a small hydraulic model for predicting the operation of a full-sized structure.

Erosion Below Dams

Whenever flood flow has to be carried over or through a dam across a stream, there is danger of a serious erosion of the stream bed below the dam. This menace to the dam is greatest with dams built on a soft foundation, such as clay, sand or gravel, where a solid rock foundation is not available. We have experimented with several devices for destroying the energy of the rapidly



FLOW ACROSS DOUBLE-TRACK RAILROAD EMBANKMENT

Fifty cubic feet per second flowing over a ten-foot section of full-sized embankment. Depth on upstream rail 1.3 feet.

MEASURING THE OBSTRUCTION

TO FLOW OF WATER CAUSED BY PILE TRESTLES. THIS VIEW SHOWS A FULL-SIZED SECTION OF A RAILROAD PILE TRESTLE BENT. FIFTY-SIX CUBIC FEET PER SECOND FLOWING PAST PILE BENT.

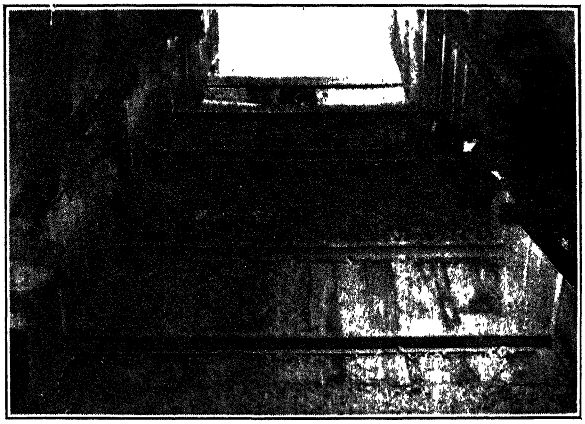
flowing water and for protecting the bed of the stream from dangerous erosion.

Flood Protection for Ottumwa, Iowa

At the request of the city officials, there was constructed in the hydraulic laboratory a small-scale model of a stretch of the Des Moines River about three miles long through the City of Ottumwa. On this model experiments were made to determine the effect of various cut-offs in the river channel in reducing flood heights and dangerous erosion. The results obtained proved highly satisfactory and are being used in planning protective improvements that will cost upwards of a million dollars.

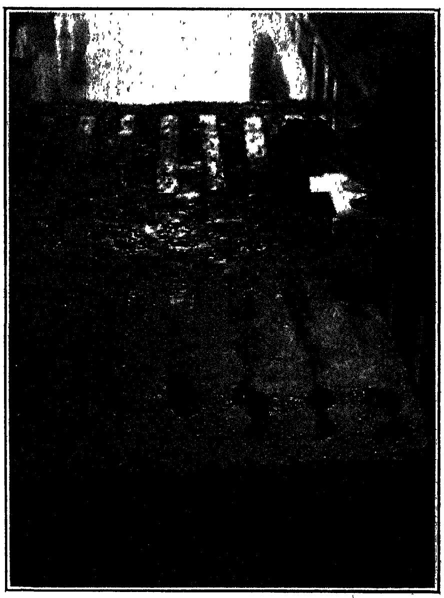
Diverting Flood Water Across a Canal

Where flood water was doing much damage on account of an inadequate outlet, it was proposed to divert the flood water across a canal into a river.



FULL-SIZED TEST SECTION
OF DOUBLE-TRACK RAILROAD EMBANKMENT TEN FEET IN LENGTH.

At the request of the U. S. army engineers, laboratory models of various types of gate structures were made and tested until a satisfactory type was developed. In this manner at a cost of only one per cent. of the completed structure, it was possible to compare a number of quite different types of proposed devices and to select the one most suitable.



FULL-SIZED TEST SECTION
OF HIGHWAY EMBANKMENT, TEN FEET LONG WITH TWENTY-THREE-FOOT CROWN.

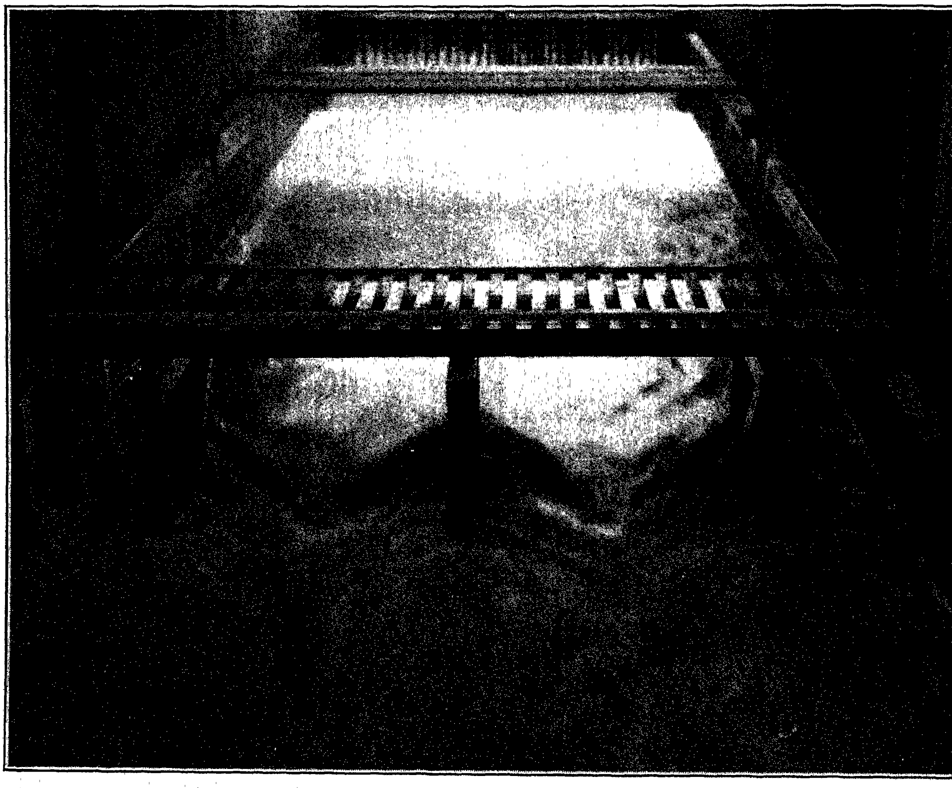
Flow Through Gates

In some important titles to water rights and contracts regarding flow through gates, dating back over a hundred years, it was found to be practicable to duplicate in the laboratory the original gates and to calibrate them for all openings.

Flow Across Highway and Railway Embankments

During high floods it frequently happens that a part of the flood discharge

FULL-SIZED TEST SECTION
OF HIGHWAY EMBANKMENT, TEN FEET LONG WITH A TWELVE-FOOT CROWN.



MEASURING OBSTRUCTION OF PILE TRESTLES

TO THE FLOW OF WATER. PILE TRESTLE BUILT TO ONE FOURTH SIZE OF TRESTLE. THIS MODEL REPRESENTS A PILE TRESTLE FORTY FEET LONG.

flows across embankments that have been constructed for highways and railroads. In order that flood protection works may be intelligently designed, it is necessary to estimate the amount of past flood discharges. For this purpose a knowledge of the rules and coefficients for flow over embankments is essential. To obtain such information short sections, ten feet long, of full-sized highway, and both single track and double track railway embankments, were constructed in the experimental canal; the amount of water which could flow across these embankments at different depths was then measured.

Bridge Piers

For generations past the amount of the obstructive effect of bridge piers in interfering with the flow of streams has been a subject of debate. Many experiments have been made in the laboratory on models of bridge piers of various shapes and sizes to determine the degree to which they retard the flow in the channel. At the same time careful studies have been carried on to determine the effect of the piers in producing disturbances in the flow of the water by which erosion of the bed and banks of the channel may at times be dangerously increased.

Flow Through Trestles

Trestle bridges are still much used for both highways and railways. Their effects on flood heights is a live question on which information has been almost entirely lacking. Extensive experiments to throw light on this subject have been recently carried out.

All this hydraulic laboratory research at Iowa University has been under the general direction of Professor F. A. Nagler.

The different problems that have been enumerated cover a wide range. Some relate to the fundamental laws of hydraulic science, problems through whose solution we may hope to advance the whole field of hydraulic engineering. Others deal with the reliable determination of experimental coefficients, giving data of definite practical value in the ordinary daily work of the engineer. Still others, such as the reduced-scale models of proposed construction, may be chiefly valuable in connection with a single location. They are most useful in trying out varying proportions and devices, in directions that are not subject to theoretical computations. They also are of great use in demonstrating how a completed structure will look and act and so are of invaluable assistance in helping to decide between different proposed types of device. In our experience a study of a model costing not over one per cent. of the cost of the full-sized structure has saved many times the cost of the study by securing the most effective and economical design for the need to be met. To limit progress in hydraulic engineering to such as can be accomplished through critical and experimental study of full-sized structures after they have been built is too slow a method for present-day needs. A most elementary experience in testing models of hydraulic structures will quickly demonstrate that often a surprising—almost wonderful—improvement in their design for the purpose of securing some wished-for results can be obtained by modifying the original design by changes that are quickly and economically worked out by changes in the model.

Hydraulic engineering is made interesting by the fact that the solutions of its problems can never become standardized. Every project in hydraulic construction presents its own peculiarities in situation and conditions, peculiarities requiring individual solution. Probably this fact has contributed largely to the great expansion of interest in the building of hydraulic laboratories in recent years. Additional facilities in this line will apparently continue to be needed for years to come.

SCIENCE SERVICE RADIO TALKS

PRESENTED OVER THE COLUMBIA BROADCASTING SYSTEM

CRYSTALS

By Sir WILLIAM BRAGG

DIRECTOR OF THE ROYAL INSTITUTION, GREAT BRITAIN

I HAVE found it rather difficult to choose a title for this short talk. At one time I thought of calling it "diamonds" because the diamond is the king of crystals. But when diamonds are mentioned every one is apt to be thrilled rather with their extraordinary value in money than with any other characteristic. And that is not at all what I want to talk about. There is that in diamonds and all crystals which is much more wonderful than the curious fascination which they exert on lovers of jewels.

First of all let me remind you that crystals take on innumerable forms. Diamonds and rubies and other precious stones are recognized as crystals by every one. We have all seen crystals of snow and ice, of sugar and of salt. Most people have picked up crystals of quartz or rock-crystal, and wondered at their clearness, at the perfect flatness of the faces and the sharpness of the edges. Of course, a drug-store or a chemical laboratory is full of crystals of many kinds.

Those who work in metal find that all their materials are crystalline in character more or less—and indeed the crystals in a metal can often be seen by the naked eye. The strength of a piece of metal depends very directly on the size and number of the crystals which it contains. The break-down of a metal structure is sometimes due to the fact that the small crystals are apt to grow into large ones, especially when there is much vibration; and that makes for weakness.

When we begin to look more closely at the things about us we find crystals everywhere, and I must tell you in a moment how this is done. Even our bodies are partly crystalline: there are crystals in bones and teeth. Still more surprising is the fact that there are crystals in hair and wool, in cotton and silk and rubber. In fact, there are crystals or something approaching thereto in all the things about us. And the strange fact is that this crystalline form, though it be generally unobservable by the eye, is of first-rate importance to the behavior of substances, to the part which they play in nature and to the use we men make of them. Consequently it becomes important both for the sake of pure science and for the sake of industry to find out what this crystalline structure really is and what we can do with it.

Now in recent years we have been fortunate enough to discover a means of looking into the nature of things more closely than ever before. We use the X-rays. It is not very difficult to get a general idea of the way in which the X-rays can do for us what ordinary light can not. The fact is that X-rays are also a form of light; they are of the same nature as light but of a very different quality. They are far finer in texture. The use of radio transmission has made us more or less familiar with wave-lengths in the ether; waves of a few hundred meters or yards are commonly employed. Light also consists of waves in the ether, but they are about

a thousand million times shorter than the waves of radio transmission. The eyes of living creatures are so made that they can detect these waves, and in doing so, are able to see. They can not see wireless waves; neither can they see X-rays, the waves which are ten thousand times shorter even than the waves of light. Thus we get the idea of a wide range of quality in these waves, but only a small range affects the eye and can properly be called light. Our eyes may be likened to a radio set which can only take in waves within a certain narrow range of frequencies. The vision of some people is still more limited than that of the average person. We say that such people are color blind.

What should we see if our eyes could take in a wider range? We should have new colors presumably, of which we can no more form an idea than a man who is color blind to red can imagine what red is like.

One thing only we can be sure about: the shorter the wave-length the finer the detail that can be observed. Small things want small waves to show them up. One can get some kind of parallel effect in radio itself. The long waves that are used swing round hills and buildings, so that the listener can often hear though a straight line can not be drawn from the receiver to the source without passing through solid masses; hearing may not always be so good but it is generally there.

Now light waves would be of no use if they behaved like that. If they did we should swim in a sea of light but it would be much the same in all directions. Whichever way we looked we should be receiving light from all the surrounding objects; we should have to exercise care even to sort out whether a thing was in front of us or behind. We must have light that turns corners as little as possible. Even in radio transmission when a so-called "beam" is wanted—a ray which will keep more or less straight without spreading—short waves of twenty or thirty meters only are employed. Now small details can be kept distinct only when the rays of light from them keep very straight. For this reason there is a limit to the smallness of things that may be seen by the aid of ordinary light; not even with the aid of the microscope can that limit be overstepped. In the same way it might be possible to detect the presence of a mountain by its effect on radio transmission; but radio could not be used to find a house or a tree.

But the X-rays enable us to see, if I may use the word, what light can not show us. Of course, we have to replace our eyes by specially made instruments. And when we use the X-rays we find ourselves in a new world which is always about us, which has to do with the structures of ourselves and all our surroundings and with the way in which those structures are fitted for their work. This new world has hitherto been hidden from us.

First of all, we are struck with the constant tendency in nature to arrange in order the atoms of which all things are made. The carbon atoms which make up the diamond are arranged in a beautifully simple pattern, one of the most regular of all the patterns we find in crystals; and no doubt we have here the reason why the diamond is so hard. When it is rubbed against other substances in which the forces that tie the atoms together are less strongly and systematically combined, it is the atoms of the second substance that must shift, while the diamond remains unchanged.

With the aid of the X-rays we can peer down into the pattern of the ice crystal, so fine in detail as to be far beyond the power of light to examine, and we see the atoms of oxygen and hydrogen arranging themselves to make six-sided figures which, when multiplied

enormously, make the crystals of snow and ice with which we are familiar.

There is a certain pattern, requiring only a few atoms of carbon, oxygen and hydrogen, of which nature makes wide use in all plant life; all plants contain tiny crystals formed by repeating this pattern. We are beginning to understand the structure of this unique substance called cellulose, which is obviously of first-rate importance to every living thing that is rooted in the ground.

There is a certain way which carbon atoms have of stringing themselves out into long chains with special little groups at each end. Of these also we begin to see and measure the details, and get a first idea of how their structure affects their properties. These are the fats and oils, alcohols and paraffins. And so on.

It is easy to understand why the crystal form is now being so eagerly studied. From the purely scientific point of view the research is fascinating, while on the industrial side every one who handles materials containing crystals, and that is a wide range, metals and stones, hair and wool, cotton and rubber and paints, and a host of other things, finds that the behavior of what he handles depends always to some extent, sometimes to a large extent, on the crystals which it contains.

THE PAST AS LIVING

By Dr. JOHN C. MERRIAM
PRESIDENT, CARNEGIE INSTITUTION OF WASHINGTON

THE words past, present and future have such definite significance that it is difficult to conceive of anything which could change their meaning. The present is living, the past is dead and the future unknowable. But, in reality, our appreciation of these things in individual day-to-day life is based upon narrowly limited experience. This may be illustrated by what is found if you have opportunity to take a great telescope and look out over the heavens. The astronomer will tell you that the stars and other objects examined are so far away that we do not see them as they really are at this moment. Although light travels with enormous speed, the rays bringing the image of these heavenly bodies to our eyes require a little less than two seconds to come from the moon, eight minutes from the sun, about four years from the nearest star and more than one hundred million years from the farthest objects thus far known in the universe.

So, in reality, we observe the stars and planets arranged not only according to their position in space, but with reference also to different stages in time. The nearest objects correspond as it were to yesterday; the farthest we see are, as it were, living and functioning in the age of dinosaurs. In terms of history of the earth, they correspond to a time before the Rocky Mountains were formed. Moreover we see all these things as fully real, and in operation at the same moment, though in different places and different ages.

In a recent speech I told this story of the various stages of time as all seen at once in the heavens, and in making the statement I remarked that these relative times depend upon both position in space and rate of communicating vibrations as represented by light-waves. One of my hearers remarked afterward that while I was speaking the transmission apparatus on the desk before me was broadcasting the talk throughout

the city and country, and that since no amplifiers were provided for the auditorium I was probably heard in the surrounding region before the sound reached the auditors at the back of the room. The hall was of considerable length, and the speech was being carried only by relatively *slow* moving sound within the room, but by rapidly moving radio waves outside. If, as my friend believed, the outside country was aware of each word earlier than the listeners at the rear of the auditorium, then the observing of what was happening there had a relation the reverse of that described for the stars in heaven. The more remote places in space were nearer in time than those close by.

When, as in the illustrations given, one begins to recognize past and present as if together, the barriers cutting off the past seem less formidable. Time appears then as a larger place in which to move about, and the past, which has been counted as dead, comes into consideration along with the present.

The relation of time to space as we now see it gives a changed appreciation of what the past may mean. But there are two other views of corresponding importance, both of which are naturally linked with the first. One relates to the living aspect of the past; the other concerns the unbroken or continuous nature of events through past and present.

But, in spite of all one may say, it is true that in average human life the past is something that appears relatively valueless. We say the past can not be *changed*—the future *can* be moulded. Let the dead past bury its dead—turn to the living future. And so I believe we *should* view the situation, unless the past is seen to live. But the instant the past takes on reality, it seems almost to become a part of our lives to-day. It certainly becomes one of the most important elements in moulding the future. It is largely regarding this point that I am speaking.

In general the more remote a thing seems in time the less its reality, and with this goes naturally the assumption of its relatively sharp separation from anything concerning our personal lives. But it is upon the vitality of the thing in the past that our interest depends. Though fading into dust, the flower we find upon the coffin of an ancient king stirs again the springs of human tears, as when placed there long ago it symbolized a last caressing touch.

Recently in a great ruin in the Southwest I examined the dwellings of an ancient race that lived at Mesa Verde. The beautifully constructed dwellings, in caves high up on the canyon wall, made one realize the presence there of many generations that struggled with the peculiar problems of that arid region.

In one room of these buildings the smooth covering of mud, plastered upon the wall, had fallen away. Examining the texture of the material I noticed that the lower coating was marked with innumerable prints of fingers. The first masses of clay had been pressed carefully into the spaces between the stones. The marking of each finger, every joint and corrugation had been left on the surface. This work was not merely that of indefinite human beings of ancient time. It represented an individual man, who doubtless bore a name, had friends, perhaps also a family. Whether this was his home or only a place in which he shared the comforts and protection of the community we may never know. I trust that when this particular piece of work was finished, he was cheered by having some one say to him, "This looks good to me."

Not far from these cliff dwellings I stopped at a trading post to buy some Hopi Indian pottery. The manager, a man with an inquiring mind, showed me a slab of rock from a nearby quarry, and upon it a peculiar impression. The Indians had called attention to the fact

that in this solid rock were many "cattle tracks." Some of the trails crossed the rock and excavation showed them continuing into the hill. The Indian knows "real tracks" from "might be tracks." He had no doubt about these particular ones. In the same formation are many skeletons, but cattle do not appear among them. The great bulk of the remains are ancient American camels, which also have cloven hoofs. These rocks belong to an age antedating the last great period of mountain making in America. Millions of years would be needed to give the measure of their remoteness in time. But over this arid landscape of to-day the Indian pointed out the trail of cloven hoofs in the rock.

As one travels over the earth, the wonders of these living pasts are multiplied, sometimes made known by science, sometimes by instinctive recognition of untutored students of nature such as the Indian. Always there is borne in upon one the inescapable reality of a vast stretch of time linked with the present.

Commonly the elements of the story as we find it are only isolated episodes. There are few places where one may see it illustrated in such a manner as to impress upon us the picture of its reality, continuity and scope. As nowhere else in the universe we find at the Grand Canyon of Arizona the evidence of moving events in the clear order of their occurrence, and so visualized that one sees, as it were, the panorama of history in operation. This story illustrates at least one thousand million years of action so presented that one may not mistake its meaning.

I have already stated that in looking out over the heavens we see many stages of time in different places. In the Grand Canyon we see a vastly longer stretch of time with all the steps or stages shown, as it were, in operation at one place and at the same moment.

In the vast wildernesses of the past, such as are encountered in the Grand Canyon region, one may explore with a sense of reality like that in the wild and unknown regions of the earth to-day. The shifting continents of ancient time —the changing seas—world after world of strange forests and creatures that exceed the weirdness of fiction—pass under the adventurer's eye. So fully aware is one of what they represent that they are no longer dead, but come into new life through a resurrection made real by the interpretation of science.

These elements of the world from past time illustrate the interlocking of events so that all appear as one story. In their continuity they also interpret in an extraordinary way the modes of operation in nature, which we call laws, operating in similar manner throughout time and space.

Once they are conceived as reality, and as expressing a continuous process, the past becomes the basis upon which the present and the future must be built.

Some years ago, a man whose conduct had been investigated, because he did not agree with others as to how public affairs should be conducted, was reported to say that, considering his recent experiences, he would be happy if he could be "as sure of his past as he was of what he would do in the future." In this instance, the future was improved by study of the past. So with reference to the story of life as a whole. It is the longer reach of acquaintance with history that gives us the best guide for the future. We may not change the past, but we may build upon it. We may not wholly determine the future but we may mould it according to what we learn from the past. Those are wisest who build upon the longest experience extended into the farthest reaches of the future.

The tendency of modern science to

consider the relation between time and space—or, in another sense, to disregard what have seemed to be barriers in space and time—has made possible some of our greatest advances in knowledge. But this broad-mindedness is not found only in science. It has expressed itself in business, where more and more great projects not only look forward to a more distant future, but build themselves upon the broad foundations of long experience.

Not only does wisdom indicate our need of knowledge for the whole of space and time. It also is clear that no generation may live to itself alone. There may be no higher degree of selfishness than that of any generation which disregards both the future and the past and denies to those who have made sacrifice the right of the continuing influence of their accomplishment.

So, as an illustration, it is a part of our duty to-day to guarantee that the poppies that grow in Flanders shall represent a widening circle of influence from lives that have not been lived in vain.

LIGHT AND THE GREEN PLANT

By Dr. JOHN M. ARTHUR

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THE present state of our knowledge regarding the nature of light is well expressed by the following dialogue:

"What is light, Mr. Staller?" asked the professor of freshman physics.

"I did know, but I have forgotten," replied the freshman.

"That is too bad! So far as I am aware, you are the only man who ever knew and now even you have forgotten!"

While we are uncertain as to the exact nature of light, in this modern age of reason we are naturally interested in finding out more about it, what its characteristics are, how we can measure it, what effects it has on plants and animals. No one doubts the supreme importance of light. Even primitive man must have been impressed with the importance of light to his continued existence. In the first chapter of Genesis light was the third act of creation. After orienting the heavens and the earth the next logical act of the creator was to put energy into the system, the energy of light.

Contemporary physicists think of light as radiant energy visible to the human eye. This includes the primary colors and all their various shades, red, orange, yellow, green, blue and violet, which can be separated from sunlight by means of a prism. The word "light," descriptive of the third act of creation, necessarily included the shorter rays not visible to the eye, the ultra-violet, X-rays and cosmic rays, since these are a part of the same system of radiant energy. The longer rays beyond the visible at the red end of the spectrum, the infra-red and radio waves, fit naturally into the same general scheme of radiant energy and were also originally included in the word "light." At the risk of being accused of inaccuracy in terminology we will use the term sunlight in the broadest sense to include all regions of radiant energy received from the sun.

Sunlight is the great source of energy upon the earth. Moonlight has been thought to exert some influence on the growth of plants, but on account of its exceedingly low energy value it has little or no effect on the process of photosynthesis—the process in which the green plant uses the energy of sunlight in the

synthesis of sugar, starch and cellulose. We naturally think of three main regions of sunlight: the infra-red or heat region; the visible region, including all the primary colors, and the ultra-violet region. We are interested in knowing whether these regions affect plants equally in proportion to their relative energy values. More than 50 per cent. of sunlight is in the infra-red. Green plants grown from seed under a dark glass or other filter which transmits only infra-red appear white, because of failure to develop the green pigment, chlorophyl. The plants will continue to grow until all the food material stored in the seed has been used, but they will weigh no more than similar plants grown in a dark room and will eventually die. This region of sunlight apparently has no value to plants other than a temperature effect. The energy absorbed aids in the evaporation of water and in increasing the temperature of soil and air.

The other extreme of sunlight, the ultra-violet region, has been found to be especially important in the life of the animal. The ultra-violet of sunlight which is not transmitted by ordinary window glass produces vitamin D, the vitamin which prevents rickets by inducing calcium fixation in the bone tissue of young animals. So far as has been determined, there is nothing comparable with this in the case of plants. Several species of flowering plants have been grown under a glass which transmits 80 per cent. at the extreme ultra-violet limit of sunlight and no differences have been observed in the growth habit, time and amount of flowering or amount of green tissue produced as compared with plants grown in an ordinary greenhouse. We have yet to find any distinct advantage to the plant in growing it under a glass which transmits the extreme ultra-violet region of sunlight. When plants are grown as food for animals, however, there is a possibility that some plants grown under a glass which transmits this region will contain more vitamin D than those grown under ordinary window glass.

On the other hand the ultra-violet of sunlight has not been found to be definitely injurious to plants. Experiments have shown that the short-wave ultra-violet produced by a mercury vapor arc lamp in quartz is very injurious. These rays will produce considerable injury on the leaves of tomato plants in an exposure of 30 seconds. It is interesting to note that this region is quite generally toxic to both plant and animal cells where it is absorbed. It is effective in killing bacteria and in killing the virus which produces the mosaic disease of tobacco, as well as producing violent sunburn on our own skin. Fortunately this destructive radiation in sunlight is absorbed by our atmosphere so that it does not reach the surface of the earth. The exposure time necessary to injure plant tissue increases rapidly with increasing wave-length, and it is believed that the ultra-violet limit for sunlight could not produce the typical ultra-violet injury upon plant leaves. It can not be pointed out too strongly, however, that one needs to overstep this extreme limit for sunlight by an extremely narrow margin to produce great injury upon plants.

The visible region of sunlight is most important in the unique process of green plants, photosynthesis. Approximately 45 per cent. of the total energy of sunlight is in the visible region. For this reason sunlight is a more efficient light source for growing plants than the ordinary Mazda lamp which has only 4 per cent. of its light output in the visible region. The energy of sunlight is absorbed by green leaves and used to build up carbon compounds such as starch, sugar, cellulose and wood out of carbon dioxide from the air and water from the soil. This process is not effi-

cient. It has been estimated that less than 1 per cent. of the total energy of sunlight falling upon the leaf is used. Yet inefficient as it is, this process is the ultimate and sole source of energy for our food and fuel supply.

Most of us unthinkingly regard sunlight as a more or less constant value. When we observe the brilliancy of a battery of electric flood lights the first question we ask is, "How does this compare with sunlight?"

The answer is, of course, that the lamps do not compare with sunlight. Electric lamps in general are infinitely more constant. Sunlight varies in both quality and intensity from minute to minute, day to day and season to season. Yet all these variations have limits and we realize that plants somehow manage to grow within these limits. We might conclude from this that plants are insensible to wide variations in light quality and intensity, or even that they will grow in about any quality or intensity. Only by exceeding the limits of intensity, quality and duration ranges of sunlight can one be convinced that, after all, the plant not only is not indifferent to these changes, but is attuned to some of them and is easily injured whenever the natural range is greatly exceeded in any direction.

In order to test some of the effects of light quality several species of plants were grown in a greenhouse covered with a red glass filter which transmits none of the blue region of sunlight. These plants very much resembled those grown in a dark basement except that the green pigment, chlorophyl, developed. The stems were very long and weak and the leaves were narrow and thin with a tendency to roll from the midrib towards the margin. Similar plants grown in another greenhouse covered with a blue glass which transmits no red were small plants, normal in appearance except considerably dwarfed. Neither the red nor the blue region of sunlight is sufficient to grow normal plants. Some light energy from both ends of the spectrum is required.

It is well known that in our latitude the length of day increases from the winter solstice in December to the summer solstice in June and then decreases again. Light intensity follows a similar seasonal increase and decrease. Average temperature shows a corresponding increase and decrease reaching a maximum and minimum, in general, a month or more later than corresponding points on the daylength and light intensity curves. That is, while the longest days of the year come in June in our latitude the highest average temperature occurs in July.

Likewise it is well known that certain plants flower only in the spring or fall. Others flower only during the summer, while a few plants flower continuously during the growing season. It is evident that plants are attuned to certain seasonal climatic factors as regards flowering. In order to study the effects of these factors it is important to be able to control all climatic factors and vary each one at will. Garner and Allard, working at the U. S. Department of Agriculture, showed that some plants which normally flower in the fall, such as the late cosmos, could be made to flower in early summer by exposing the plants to daylight from 9 A. M. until 4 P. M. each day. These plants were attuned to flower only on short days. At the Boyce Thompson Institute for Plant Research plants have been grown in an artificial climate using, in one case, daylight supplemented by artificial light each night and in another, all artificial light. Forty-eight 1,000-watt electric lamps of the ordinary incandescent type were used as a light source to supplement sunlight in the first case. These lamps were carried upon a crane which was moved over a greenhouse at night

and moved off again during the day so as to avoid shading. In the second case twenty-five 1,500-watt lamps were used as a light source in a basement room approximately 11 feet square. Temperature and humidity were accurately controlled by means of standard air-conditioning equipment and the carbon dioxide concentration of the air was closely regulated.

Many plants grow well in such an artificial climate. Red clover plants were grown from seed to flower in thirty-eight days, while the grains, spring wheat and barley, were grown from seed to flower in the same time period. While many plants grow well when illuminated continuously, certain plants, such as the tomato, require approximately a six-hour period of rest in a dark room each day. The length of day affects flowering whether sunlight or artificial light is used as a light source for growing plants. That is, long day plants such as lettuce and radish which normally flower in the early summer flower on daylengths greater than twelve hours. Everblooming types, represented in these experiments by buckwheat, flower on all daylengths from five hours to twenty-four, while the height of the plant increases regularly with daylength. Short day plants which normally flower in the fall, such as salvia and ragweed, flower on short days of twelve to fifteen hours or less. Many victims of hayfever in southern Illinois have no difficulty in recalling that they normally start to sneeze on or about August 15 each year when the ragweed comes into flower. These unfortunates are indirectly attuned to daylength.

When we are able to reproduce natural conditions in artificial climates more accurately we will no doubt find many other plants attuned to either one or a group of natural climatic factors which vary with the season. Such studies, we believe, will result in a more intelligent handling of plants. While we are at present mainly occupied in a study of some of the fundamental conditions associated with plant growth, we hope at the same time to remain alive to the possible application of our studies to the benefit of those of our own generation.

MENTAL HYGIENE

By Dr. WILLIAM A. WHITE

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THERE is nothing mysterious about mental hygiene except that we have always thought of the mind, when we have thought of it at all, in terms of our ignorance about it, and have felt that it was a great unknown territory. In fact the study of the mind, psychology, until recent years, was taught as a branch of philosophy. It is only within the present century that it has won a place for itself among the natural sciences, more particularly among the biological sciences or the sciences that treat of living beings.

I have said there is nothing mysterious about mental hygiene. We have long been familiar with the term "hygiene," and we have recognized its significance as an effort to live healthy lives, but we have thought of it in terms of our physical bodies and their function and not in terms of our minds. We have recognized that hygiene requires a reasonable amount of rest, a reasonable amount of exercise, good and properly selected food in adequate but not too great quantities, pure drinking water and a thousand

other things. But we have not recognized that all these, and many more, are really only means to an end, and that what man lives by really is not food and drink but ideas and ideals, desires and hopes, aspirations and ambitions, and these are matters of the mind. A recent book by a noted Italian on this general subject sets forth his objective in the following vigorous words:

> I write . . . to dislodge indifference to the momentous subject of eugenics, to lay open to the public conscience the dangers of bad habits and of certain defects of our present school system, to call attention to the responsibility of the government, to fan the fires of the inexhaustible energies of our race which now lie sleeping under the ashes of inertness, of ignorance and of old customs. I write for the invigoration of our spirits and for the discipline of our lives in health, in strength, in new religion, in beneficent liberty.

This is a rather ambitious program, but it is along the lines that I have suggested, for it deals not with the material needs of life but with the immaterial and more important things that we live by. Further than that, this program has other very specific references and indications. Man has never worked out a very adequate understanding of his mind. He has always accepted what he found there. People believe or doubt, they hope and they fear, but they rarely ask themselves why they believe or doubt, or why they hope or fear. These mental facts have been accepted and acted upon practically without any consciousness that they are subjects, or could be made subjects, of scientific inquiry. We are accustomed to apply our science only to concrete things which can be seen, to animals, to plants, to planets, to crystals—not to these intangible ideas which seem to escape us the moment we attempt to inquire into them. But man is a very ingenious animal. The possibilities of his inquiring mind are unknown but capable, without doubt, of very much greater development even than they now have. And so with that everlasting curiosity of his which has unearthed so many secrets of nature, he has now turned his attention to these intangible ideas. He has become for the first time profoundly interested in his own affairs. He is applying scientific methods to their study and elucidation, and he is beginning to insist that the great facts of science as they are discovered in all its various realms shall be made to point in his direction, that there shall be asked the question, "Of what value is this fact to me, how can I profit by it, how can mankind be improved by its application?"

The twentieth century has given birth to this great interest, which is rapidly and certainly gripping the imagination of peoples in all parts of the world, and man is applying his ingenuity in attempting to discover answers to the questions that have puzzled him for generations: Why do people become mentally ill? Why do they become criminals? What is the meaning of unhappiness and discontent? How can habits that are destructive be modified? How can the energies that are being poured into useless activities be recaptured for the common good?

Difficult as some of these questions may seem, unanswerable as they may appear, it is nevertheless true that we are moving in the direction of better and better solutions; that progress is being made, slowly perhaps, but, after the manner of science, with certainty; that the domain of false ideas and traditions, of superstitions and taboos, of nameless fears, of destructive tendencies—that the domain of these hobgoblins of the mind is being gradually invaded, that they are being studied with the purpose of their modification and ultimate conquest. Mental disease is beginning to give up its secrets. We are beginning to learn how to deal with problem children. We have already

glimpsed the problems which the criminal presents and have some idea of the direction in which to look for their solution. We have attacked the difficulties and maladjustments of the industrial world. And in a thousand and one ways we have made efforts to find out the laws which obtain in the sphere of the mind and which must be observed if one is to be mentally healthy. All these things and many more are of tremendous significance to every one, and it is the purpose of my few remarks to direct your attention to them, to invite your interest in this comparatively new field, for you will, I am sure, see unfolded in these various directions during the next generation facts of the utmost significance to the welfare of mankind.

Many of you who are listening to me will undoubtedly say to yourselves, "This is all very interesting but what application has it to me? I am not insane, I do not expect to become insane, there is no insanity in my family, my friends and acquaintances are all self-sustaining, mentally well individuals so far as I know. This whole matter is one only for the exceptional individual, who will be adequately cared for by the means that are provided by the state and a few private hospitals." If this is your conception of the significance of the problem of mental illness, may I say to you at once that you are quite wrong? To-day the number of beds in hospitals for mental disease throughout the United States is very nearly as great as the number of beds in all other types of hospitals combined; and a recent report shows that of the beds under construction there are actually more beds being built right now for mental diseases in the United States than for all other diseases put together. In other words, you are certainly occasionally sick, almost every one of you, and these figures would indicate that you have on the whole pretty nearly as much of a chance of being mentally sick as you have of being sick in any other way. Fortunately, this statement is not quite true, because while there are as many beds in mental hospitals as there are in all the others, the number of patients that pass through these beds is much less because the patients stay on an average very much longer in the mental hospitals than they do in the general hospitals. Nevertheless, when I tell you that the statistics recently compiled of New York State, which I may remind you contains approximately 10 per cent. of the population of the United States, show that of the residents of that state one person in every twenty-two over the age of fifteen spends a certain portion of his time in a hospital for mental disease during the course of a generation, you will begin to see the significance of mental disease and to realize that after all you individually may not be as immune as you have been wont to think.

Therefore, mental illness is not rare, it is not exceptional, it is not something which may not affect you individually or those whom you may love. No one is immune; and I have no doubt that many of your friends and many of the families the members of which you know could tell you of cases of mental illness which they know about or which are actually present in their own families, if they would. Let me add to this somewhat startling picture the fact that the number of patients in public institutions for the mentally ill has increased something like 300 per cent. in the last half century. This does not mean necessarily that mental disease itself has increased at any such rate. It is partly an expression of the increasing confidence of the public in the mental hospital. But it is nevertheless a somewhat alarming state of affairs, especially when I tell you that according to the statisticians we are due to keep up this rapid rate of increase for the next half century at

about the same pace that it has been occurring during the past fifty years. If you could visualize this adequately it would be translated first into the material things—hundreds of millions of dollars for hospitals, hundreds of millions of dollars for salaries and wages for personnel to take care of these sick people and hundreds of millions of dollars wasted because of the inefficiency and failure of earning capacity of these patients while ill. It would represent also a loss to society of the services of these thousands of individuals not only expressed in money but in the many other ways in which their services would have been rendered. Husband and wife are separated; parents and children are separated; households are broken up; families become dependent upon public charity, and in many other ways the loss on the material side is enormous. But think in addition what it means in suffering and death, in the failure to function adequately as caretakers and directors of the new generation represented by the children. Think what it means in terms of crime and anti-social conduct generally, of wasted and aborted effort in all sorts of directions.

Perhaps no one affliction of mankind is so far-reaching and so destructive in its results both to the individual and to society at large, and all these things affect you, my listeners, very directly. You are now paying a very large percentage of your taxes to take care of the mentally ill, in one form or another. You are subject to all sorts of regulations and restrictions which were made because there are some people who need to be controlled. You are subject to the contagion by suggestion of all sorts of aberrant ideas which may be on the road that leads to mental illness. You are in every conceivable way closely affected by this great menace, and it is for you to assist all who are making the effort to minimize the ill effects that flow from this source as far as possible, to assist the mental hygiene movement, which has as its ultimate goal the prevention of mental disease, to help secure the adequate care of those who are ill at the earliest possible moment so as to insure the greatest number of recoveries, and in every way to spread that knowledge of mental disorder and that desire for mental health which is calculated to counteract it. Just think of what has been accomplished with such a disease as typhoid fever, for example. During the past year, of eighty-one cities in the United States of over 100,000 population, five reported no deaths from typhoid fever during the year, whereas twenty-eight reported less than one death per 100,000. It is hardly to be expected that any such results as that can be even hoped for in the realm of mental disease, because in a very real way mental illness of one sort or another (and in this term I include what are ordinarily known as the neuroses as well as the more serious mental sicknesses), represents the price that we pay for being civilized, and the progress of civilization seems to be closely interrelated with this whole question of mental illness. But what we can do is to undertake to see that we do not have to pay too great a price. We can make a concerted effort to reduce the cost of the advantages of civilization, and there is every reason to believe that this cost can be very materially lessened. So I plead with you to join your interests with ours, to help wherever you have a chance.

CHEMICAL ATOMS AND SUPERATOMS[1]

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In a recent essay[2] the writer attempted to demonstrate that the atomic conception, when used in the sense of structural or functional units, is a tool universally employed. It became evident that the clear understanding of any problem involving the behavior of a system requires, first, an analysis to reveal and define the structural elements that are functioning which must of course be visualized or selected on a suitable scale; and second, the effective synthesis of these elements into a functioning whole. In developing this picture a serious gap was encountered in the field of colloid chemistry, which Wo. Ostwald has so effectively characterized as a world of neglected dimensions. The difficulty encountered here arises from the fact that the classical atom of chemistry is still a living conception, and that chemists are continually trying to solve the problems in this field by means of the older forms of this concept. Such efforts have yielded only fragmentary results. It seemed clear that if the atomic conception could be adapted to the problems of the colloidal field, many things would be facilitated.

The effort to extend the atomic conception in a fruitful form into the field of colloidal phenomena is justified by the fact that colloids in spite of the intensive investigation of the last few decades constitute the no man's land of physiology and medicine. The anatomists have pushed the boundaries of their knowledge of tissue structure and organization to great lengths and are reconstructing tissues in the form of plastic models in such perfection of detail that the actual processes of health and disease can be clearly visualized to the absolute limit of visible structural detail. There is no possibility, however, that the resolving power of the microscope can be increased to the point that the elaboration of the toxic products of metabolism of the tubercle bacillus, for instance, can be witnessed, or that the first effects of these products upon the tissue cells of the host may be traced. The limits of the microscope are determined by the nature of light, and so these problems necessarily fall back into the field of chemistry, however much we may regret it, because—and we might as well admit it—although the limitations imposed by the microscope are great, those existing in chemistry are infinitely greater. It therefore becomes an urgent duty for chemists to reconnoiter the no man's land lying between and in front of the organized forces of classical chemistry and those of visible morphology in order to make contact between the two forms of attack. It is in this area that the next great advance in the conquest of life and death will be made. The battle-field lies ready; what is lacking is a general with a suitable plan of battle. While waiting for the great leader there is no objection to carrying on with exploratory raids, and this paper constitutes a report on such a raid.

The effort here described is in the nature of an exploratory reconnaissance. We wish to attempt to blaze an atomic trail across and through this colloid wilderness. Entering the woods on the chemical side, we hope to come out in the field of general biology. Such a trail

[1] In this paper only the most familiar types of chemical facts and concepts are used. For this reason in order to keep the story moving the author has failed to give references to the specific sources of information or views.

[2] SCIENTIFIC MONTHLY, 29: 363–8, October, 1929.

would then constitute a temporary highway upon which workers in the field of chemistry and general physiology could maintain contact in their further explorations and developments of this world.

Since this reconnaissance is to move out from the chemical side and is to depend on the use of the atomic conception as a means of transport, it will perhaps clarify the situation to review the present status of the classical chemical atom.

Originally the term atom by definition involved the conception of indivisibility. When the spontaneous decomposition of the radioactive elements was discovered, this classical atom passed out of existence. An atom then had to be conceived as an elementary substance which might or might not be relatively stable. The views on atomic structure in process of development at present represent the chemical atom as a more or less complicated micro-astronomical system, which is composed of several or many discrete parts and which may or may not be relatively stable. The decomposition of a neutral atom may involve a simple reversible change like the loss or gain of one or a few electrons; or it may represent a profound disruptive change involving the formation of new chemical elements. The former change is characteristic for all chemically active elements, and varies as a periodic function of the atomic weights. It is analogous to the loss or gain of hydrogen atoms by a petroleum hydrocarbon. The latter change appears strikingly with the heavy radioactive elements and is analogous to the disruptive "cracking" of heavy petroleum hydrocarbons. In the former, we have a periodic recurrence of similar properties with gradually increasing atomic weights. In the latter, we have an innate instability associated especially with high atomic weights. This gives rise to a progressive decomposition in which energy or energy and helium atoms are lost. This disruption into simpler atoms is associated with the highest atomic weights. So much information has already been accumulated concerning such transmutations that it appears possible that helium is constituted of residues of four hydrogen atoms and that the remaining elements represent complexes derived from these hydrogen and helium units. Viewed in this way, we may conceive of the atomic series as being a series of structural units, each capable of acting as a unit, but composed in turn of simpler units coupled up in stable configurations which develop enough structural weakness in the higher members to undergo a controlled and gradual but spontaneous decomposition.

It is against this background of highly complex but perfectly organized atomic structures that the series of superatomic structures to be described in this paper is to be projected. Although the classical chemical atom no longer exists, the term has been retained and has taken on a new and definite meaning that seems to be accurately suited to the extensions to be developed. Its present meaning is indeed that of structural or functional units, which in turn possess an inner structural complexity of their own. Moreover, by retaining the word, we may hope to carry over into the realm of superatoms some of the time-proved traditions of thought and action of the field of chemistry. This would be particularly desirable if by their disciplinary effect they might become as fruitful in a general way in the future as they have been in a special way in the past.

Our problem then in this essay is that of finding superatoms of suitable dimensions so that we may construct a more or less continuous series from the traditional chemical atoms, through the field of colloids, to the field of visible morphological elements in the organism. In this program, it will of course be neces-

sary to learn to what extent and how chemical elements and compounds build themselves up into more and more complex edifices, which, however, still retain the essential characteristics of structural units capable of acting as a whole in chemical reactions of a higher order.

The idea that aggregates of atoms may function like a single atom in building up complexes was established by Gay-Lussac and later by Liebig in his classical work on benzoic acid in which he found the benzoyl radical acting like a monovalent atom. Very quickly these observations were extended and the interesting classical radical theory of organic chemistry was developed.[3] Later it was found that these radicals, unlike atoms as then conceived, could be attacked. This led to a modification of views and a decline of interest in this conception. Because of the influence of the classical conception of the unassailability of the atom, it seemed that an error in consistency had been made and the relation of atoms to radicals was no longer emphasized. However, this situation no longer exists, and the atom and the chemical radical are now closer together and more integrally related than they have ever been. This will appear more clearly in what follows.

In the meantime, it had become clear that in inorganic chemistry certain acid groups, such as sulphate, phosphate, nitrate, carbonate, silicate, etc., enter reaction as unified radicals. This seems to have been expected because of the associated idea, prevalent at that time, that oxygen is indispensable in acids, and consequently the idea that acid radicals that do not contain oxygen can exist was only slowly elaborated.

In the case of bases, the situation was somewhat different, and when it eventually became clear that ammonia acting as ammonium was able to play the rôle of an alkali metal even to the extent of forming amalgams with mercury interest was aroused from another angle. Gradually the transition from simple diatomic acids like hydrogen chloride to complex organic and inorganic acids and from simple bases like sodium hydroxide to the most complex alkaloidal bases was established and clearly interpreted. The continuity of these series was recognized, and the theory of electrolytic dissociation was found to be applicable to all of them, but it was not so clearly perceived that, since the chemical radicals in the higher members of the series functioned like the atoms in the lower members, they might be regarded as atoms of a kind. The radical concept replaces the atomic concept in these series as one passes from the simpler members to the more complex. Logically there is no break in passing from the atom to the most complex compound radical in these series. These radicals may therefore be regarded as an ascending series of atoms of increasing complexity.[4]

[3] "That the radical behaved like an element, had been confirmed over and over again. Not only did it enter into combinations with elements, but it could also be isolated from these combinations. How far this comparison was carried is shown by a quotation taken from a joint paper by Dumas and Liebig: 'Organic chemistry possesses its own particular elements, which sometimes play the part taken by chlorine and oxygen in inorganic chemistry; sometimes, on the other hand, the part of the metals. Cyanogen, amide, benzoyl, the radicals of ammonia, of fatty bodies, of alcohols, and analogous bodies; these are the real elements with which organic chemistry operates, and not the ultimate elements, carbon, hydrogen, oxygen and nitrogen, which only appear when every trace of organic origin has disappeared. It will thus be understood that the atoms which constituted such a group were supposed to be held together by stronger forces than those which united the group to other atoms.' " A. Ladenburg, "Lectures on the History of the Development of Chemistry since the Time of Lavoisier," p. 128–9, University of Chicago Press, 1906.

[4] Throughout this paper no effort is made to distinguish between neutral superatoms and charged superions. At this stage, it would

As investigation was broadened, it became increasingly evident that under suitable conditions certain metallic atoms, which customarily acted in simple ways as ions, were able to enter into very complex relations with other substances. Among these were conspicuous at first the various ammoniated derivatives of cobaltic and nickelic salts as well as platinum salts. Eventually illuminating clarification in this field was brought by Alfred Werner, by the development of his spatial conceptions regarding complexes of this type. Many obscure facts and relations were clarified by his fruitful ideas. Hundreds of other examples were subsequently discovered and described.

The main fact in all this for our purposes is that several metallic elements are able to associate with themselves molecules of certain chemical substances and to organize these in such a way that the whole system behaves in many respects like a single atom. These systems are conceived of as arranged in a geometrical pattern or shell around the central atom, and have no existence except through the coordinating or organizing influence of this central atom.

Such a complex structure is often very stable, contrary perhaps to expectations, and in some cases renders a compound more stable than it would be in the free state. Thus, for instance, the heavy metal nitrites, which are notoriously unstable in the free state, are readily obtained as stable complexes with hexamethylenetetramine and some other organic bases.

Many organic compounds enter into complex relations in other ways. Among the most familiar are the complexes formed by cupric hydroxide with various hydroxy acids used in the analysis of reducing sugars. The same is true for the colors developed with the Biuret reagent with proteins and many of their derived products. In fact, a very large number of color reactions depend upon the formation of a definitely organized complex. Many of the complexes formed have not been isolated and studied, while the nature of many others is still unknown for various reasons.

In many of the types and cases of chemical radicals that have been reviewed above, the complex enters into reaction like a simple ion—either acid or basic—and from this standpoint could be mistaken for such if its complexity were not revealed in other ways. But the same statement can be made about the chemical atom. It was and can be mistaken for a simple indivisible structure unless and until its complexity is revealed. Chemical radicals and chemicals atoms then have this in common, that they are both complex organizations that can and do function as a unit.

This unity of structure and function, even in the range of the atomic structures under consideration, is not, however, as simple as it might appear. The problem is complicated by the relations existing between solvent and solute. Consequently in any attempt to enter the field of biology with the tool kit of a chemist, we must sooner or later take account of water and its relations to materials immersed or dissolved in it. Water is the *sine qua non* for life, although in most considerations of vital processes it is regarded as a medium which is passive or at least relatively inert. It would, therefore, be unwise to attempt to avoid considering the relations of water to the atomic systems under discussion in spite of the difficulties involved in the subject.

In all our previous discussion, the presence and actions of water have been assumed to be constant. Our examples of chemical radicals were so selected that

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perhaps be confusing to attempt to make such distinctions. The term superatom is used loosely, and is indiscriminately applied to charged as well as neutral systems. This usage coincides with that in vogue for the atom before the ionic conception was developed.

we could do this. If we had chosen to speak of the fatty acid series, in which we have a growth of complexity in the hydrocarbon or lyophobic radical while the carboxyl or lyophylic radical remains constant, we would have seen a gradually increasing insolubility, and our reconnaissance expedition would have been seriously impeded. Such polar systems will be discussed later. In the meantime, it seems urgent first to develop an interpretation of the problem of the solution which is definite enough to enable us to accept the presence of large amounts of water within the boundaries of our superatoms. This can perhaps be accomplished by the statement which follows. We shall regard water as a feebly polymerized system. Solid or liquid substances soluble in water undergo disintegration into particles of molecular or polymolecular dimensions. Under these conditions, all dissolved substances and their components enter into relations with the water molecules of the solvent by which the properties of both are appreciably modified. Water existing under such influence we shall regard as hydration water. This water is to a degree under the influence of the molecule, radical or ion to which it is attached and will be more or less involved in the history of the component with which it is associated. It follows then that all the radicals or atomic series that we have considered have, while in solution, associated with them more or less water, and that any adequate picture of such atomic series must take this fact into account, however much it may complicate the picture. The amount of water involved may be relatively negligible as in the case of sodium chloride, and will increase gradually, in a suitably arranged series, until we reach complex colloidal molecules like proteins, which have the power of associating enormous numbers of water molecules within their relatively vast labyrinthine boundaries. Moreover, the amount of water held in this way will be sensitively influenced by a great many and even apparently trivial factors. This is shown in a prophetic way by sodium chloride, which has so little affinity for water that it normally crystallizes without water of crystallization. If crystallized at low temperatures, it comes out of solution with two molecules of water of crystallization, which are, however, but feebly held.

It therefore now becomes necessary to enlarge our picture of the complex atoms that we have discussed in order to include the water with which they are associated. Moreover, in doing this we have simplified the transition from the complex atoms of the molecularly disperse systems to those of the colloidally disperse systems. We observe simple carbohydrate molecules in molecularly disperse solution, with much hydration water, undergoing polymerization, by which they become less and less disperse, until they reach colloidal dimensions, as in starch or glycogen, retaining throughout the transition an integral relation to a large, but probably gradually diminishing amount of hydrate water. Likewise, we see the amino acids, in which the hydrocarbon radical has been materially changed by the introduction of at least one highly water soluble group into the most strategic position in the molecule, being built up one unit at a time into structures having a molecular weight of 30,000 and upwards, in water, and in most cases having a high affinity for water.

Of these two cases, the former is most difficult to discuss from the atomic viewpoint. If the views just now being developed with respect to the starch molecule are correct, the latter is built up of atomic units known as amyloses and amylopectins. Perhaps the facts developed in the study of cellulose for the development of the viscose industry reveal the essential atomicity of this complex substance. These questions remain

for time and the experts in these fields to determine.

So far as the protein molecule is concerned, the situation is different. Here we have abundant information on the properties of the various components of the series. Each member possesses two interesting traits in common with all the other members of the series; it can act as an acid or as a base, depending upon circumstances. This property, other things being equal, depends upon the presence of free carboxyl and free amino groups. The protein molecule, therefore, becomes an enormous polyvalent amphoteric electrolyte having perhaps as many as thirty positive or negative charges on its molecule at times, depending upon the characteristics of the solution in which it lies. These charges may be increased or decreased to a maximum on both sides of the isoelectric point, and when charged the molecule shows cataphoresis. In all respects, these systems behave as huge polyvalent atoms would be expected to behave. Moreover, generally speaking, they are much more stable than the radioactive elements, although they are probably at least one hundred times heavier. Unlike the radioactive elements, these atoms of life are synthesized or broken down at will (given suitable materials and conditions) by special agencies existing in their natural environment. The syntheses involved are highly specific both as to product and agencies, and give rise to a special field of biochemistry, owing to the fact that only the living organisms can be used as the test-tube and retort for the study of certain characteristics of the proteins and allied compounds. The finest analytical work in chemistry is crude in comparison with the chemistry of the organism in dealing with the detection or identification of these compounds. In short, this highly hydrated poly-functional superatom is a remarkable organization which it is at present utterly impossible to describe adequately.

In the above, we have found it rather easy after all to build up a continuous atomic series ranging in size from the simplest hydrogen atom to protein molecules having molecular weights estimated at 30,000 or even more. In this series, we have representatives all the way from rapidly diffusible molecular dispersions to complex colloidal emulsions. Perhaps it would be the part of wisdom to terminate our "trail" here without attempting to hack away the underbrush necessary to make a true contact with general biology. However, wisdom is not a normal trait of an explorer in the face of such a challenge; let us press on.

Our problem now becomes that of passing from ultramicroscopic particles having unitary functions to larger ones visible to the eye and existing as morphological elements in cells. In common with other electrically charged colloidal particles, the protein molecules undergo precipitation by suitable reagents having charges with the opposite sign. Such reagents may be other protein solutions or other chemical reagents suitably chosen. Such changes often involve the production of visible aggregates, and in many instances the native protein can be recovered unchanged. But they are probably analogous to only a portion of the processes occurring in the living cell. For instance, all precipitations and engulfments of foreign masses by leucocytes, whether they be inanimate colloidal particles such as carbon or living cells such as bacteria, probably depend upon such colloidal chemical precipitation, perhaps frequently initiated by mutual neutralization of electrical charges or in other instances by a chemical attraction, which here becomes chemotaxis.

Moreover, it is quite possible that one factor in the deposition of proteins in the tissues in the first case is their dis-

charge by suitable changes in the hydrogen ion concentration; and in the second case, in so far as they become insoluble, this may be followed by polymerization involving secondary chemical changes. If the process stops in the first phase, such proteins would be mobilized by suitable changes by which they recover their charges, become more highly solvated, and are thereby drawn back into the zones of greater activity. Such events may occur, for instance, during starvation when much of the structural material is mobilized.

Regardless of the extent to which such precipitations occur and the size of the aggregates produced, it is clear that these particles are lacking in some part of the freedom or structural unity that they had before. They are, we may readily see, in some degree less lively than they were; so that, although it is more than probable that some of the visible structures in cells are built up in this way and perhaps play a skeletal or orientizing rôle, it is also more than probable that the essentially living portion is composed of structural units having more chemical and physical freedom, *i.e.*, tropisms. These are no doubt built up into definitely oriented structural patterns by which they achieve, and are endowed with, special physical and chemical functions in the cell. So far as the writer knows, no such complexes are actually known, nor are any criteria by which they would be recognized known. Of course, there has been much speculation by philosophers of all times, as well as biologists more recently, as to the physical-chemical unit of life, but no such unit has been isolated by experimental studies.

Instead of indulging in speculation, let us see if we can build up a background for such a complex upon which some of its characters might be predicated. In view of what we saw above, it is more than likely that any system having the properties required would possess more polarity than any of the systems that we have considered. Such polarity is best known in connection with the fatty acids. In oleic acid, for instance, the hydrocarbon group with its inability to unite with water so overwhelms the carboxyl group that it is of little avail except perhaps to orient those molecules that lie in the water-oil interface. However, in the sodium salt of oleic acid, the hydrocarbon radical is still strong enough to prevent molecular dispersion. If, however, we concede something to the hydrocarbon radical by replacing the hydrogen atom in water with the ethyl radical, we find that in ethyl alcohol our soap forms true molecular dispersions. A similar result is achieved in two ways in the organism. Fatty acids are rendered soluble in the intestine by the bile salts, which unite with them forming a colloidally or more probably even a molecularly dispersed system. So far as is known, this device is limited to the bowel. Tissue fats can, however, be modified by replacing one fatty acid radical with the phosphoric acid-choline complex and thus become capable of spontaneous peptization and of forming colloidal dispersions. In all such cases, the change is presumably due to the influences of the substituent on hydrate or solvate formation.

Now it is interesting to note the number and variety of hydrocarbon and other side chains in the protein molecule. It is easy to imagine that all these have certain more or less specific powers to hold other radicals in complex relations. The hydrocarbon radicals no doubt attach fatty or other hydrocarbon radicals, so that complexes between fat molecules and proteins are to be expected. The existence of such complexes has been conjectured, but so far as the writer knows, no such complex having indispensable relations to life has been described. However, we may dis-

cuss at least one interesting possibility of this sort. For instance, it is well known that the brain contains a surprisingly large amount of lecithin and allied substances. It is not difficult to visualize a union between the lecithin ion and the protein molecule, and this could occur through solvate union between the hydrocarbon radicals in both or through salt formation or through both processes. Such a union of two complex superatoms of contradictory polarity would give rise to a new complex having properties unlike those of either component. But in visualizing this union, we have failed to mention the large mass and variety of other molecules including water that will be carried into the complex and that will contribute to its properties and functions. With this system and its inevitable orientation, we can easily picture the conduction of a nerve impulse, for instance, as depending upon the continuity of the water phase, and the nonconduction under narcosis as due to an inversion of the emulsion with the consequent non-conductivity of the now continuous oil phase, as was suggested some years ago by J. S. Hughes.

In the foregoing discussion, we have seen rather clearly that the most readily seen morphological components of the cell are in a relatively passive state in comparison with the more lively and more transparent components. Intermediate between these extremes, we have the various cell organs, but especially the mitochondria, and in plants the various plastids involved in photosynthesis as well as the starch and oil formation. These visible organs carry on within themselves essential functions. Their continuation, once they appear, is almost certainly provided for by growth followed by division. If, now, we should suggest that these cell organs possess the essential traits of superatoms, it might be asked, but how can atoms grow and divide? Such objections can not of course be fully answered. We know that crystals grow and that the structure is specific. We also believe that they divide. However, closer analogies in the colloid field are easily obtained in which the phenomena under consideration can be imitated so that there may be no essential mystery in this part of the problem.

The problem becomes simpler again when we deal with bodies like free living cells of various sorts. Here we have superatoms large enough to be seen readily, which still obey the same fundamental law that we have been discussing. Although microscopically visible, they often show Brownian movement; in other cases, movement is due to cilia. They often behave like charged systems, and at other times show positive and negative chemotaxis. Although they are true living organisms, they nevertheless show definite relations so far as behavior is concerned to suborganismal systems. Perhaps this behavior has appeared rather surprising heretofore; now we must expect it in the atomic series that we are attempting to construct.

The above discussion constitutes a blazed-trail of superatoms—a continuous series extending from chemical atoms to superatoms which are sufficiently large to be visible as morphological units in the living organism. We have achieved our goal and might rest our case except for the fact that several interesting points have been brought out incidentally which, if gathered up and developed, may lead eventually to a generalized description of atoms and superatoms. Such a generalized description would be useful in isolating superatoms on any scale.

(1) All the atomic series developed possess a striking structural integrity coupled with an uncanny capacity to perfect and maintain this structure. We see it in acids such as sulphurous

acid and its tendency to perfect its structure as sulphuric acid by adding oxygen; we see it in acid salts in their tendency to pick up available base to complete their structure; we see it in the protein molecule of the living organism, in its unaccountable ability to maintain its structure. It is difficult to account for the fact that only a very small excess of essential amino acids, over and above the actual minimal requirements, is needed for maintenance of the nitrogen balance. It seems that the amino acids are taken up from the body fluids with great avidity. In this respect, the protein components of the organism are as efficient as a strong acid in "gobbling up" base to complete its salt structure. If we think of it in terms of chemical affinity, we are apparently dealing with a very powerful or a highly selective type of affinity.

(2) This peculiar tendency to complete and maintain a structural unity is probably the most outstanding perceptible characteristic of these systems. It is expressed as an organizing tendency. The complexity of a given superatom is determined by the complexity of its organization. Viewed in this way, the hydrogen atom has a life, or life history, which differs only gradually from the other members of a series and from organizations commonly accepted as living organisms. The difference is essentially a difference of degree and not of kind. Creation, at least within the range in which we are discussing it, was therefore a continual improvement in the utilization of simpler parts. In the elaboration of these structures, properties are continually increasing in variety and complexity. But this, too, is not peculiar to such systems. Tyndall long ago noted that the liquefaction of a gas entails the appearance of new properties, and this is still more true of its solidification. How rapidly properties change and new ones appear on mixing several substances in suitable ways is known to every one. Consequently, the gradual disappearance of a given property or the appearance of a totally new property in any such series is entirely to be expected on the basis of the known behavior of the simplest systems. We must still admit that life *per se* is a unique attribute because we can not create it *de novo* at will. However, it must also be admitted that the individual properties of living matter exist a few at a time in non-living matter, and that living matter may differ from the other only in the complexity of its inner organization.

For instance, we usually think of self-building, self-repairing and self-steering as unique properties of living matter, but many of these complexes have these properties to a striking degree, and all chemical atoms, as well, have them to a recognizable degree.

(3) The innate tendency to build superatoms does not depend upon any one kind of chemical or physical property. It seems clear that it always depends upon some kind of polarity, but if so, the nature of these polarities is probably still largely unknown. Although many of these systems have the essential qualities of an amphoteric electrolyte, it seems that their polarities are not limited to those involved in this concept. In brief, it is not possible in chemistry to predict all types of complexes that may exist, and it is likewise impossible to make similar predictions in this field of superatoms. It will at first be necessary to isolate the functional superatoms and to develop the knowledge in this field much as it was developed for the chemical atoms.

(4) The atom, in every case, when compared with neighboring states seems to represent a state of relative stability. Considered from this standpoint, it possesses essential characteristics of a phase, and it would be exceedingly interesting

to know just what J. Willard Gibbs thought about phases in such a general sense as would be involved here. The suggestion of the phase-like nature of the superatomic systems, and perhaps for that matter the atomic systems themselves, arises from the unexpected ease of synthesis of many of them. For instance, it might be expected that so complex a system as the hemin of hemoglobin would be next to impossible to synthesize, but Hans Fischer did not find it so. We might expect that the tetrapyrrole nucleus would be synthesized around the iron atom, but this was not the procedure used. The tetrapyrrole nucleus was first synthesized, the iron was then introduced and at the last this iron complex could be coupled with the globin component. Whether the organism approaches the synthesis in this way or not is not known, but it surely is not without philosophical significance that the same terminal products were obtained by the synthetic chemist as are obtained in nature. Perhaps it was the terminal quality of the products that made synthesis of so complex a product possible. We are quite familiar in chemistry with such terminal products. Often, from a thermodynamical standpoint, they represent maxima in entropy. At other times they arise from minima of solubility or electrolytic dissociation of an equilibrium component. Glucose in the form in which we know it represents such a terminal product. Under the influence of alkali or insulin, it develops new capacities to develop still more stable terminal products. Many other cases of this sort could be cited. Perhaps, in this quality, we have one of the outstanding characteristics of both chemical atoms and superatoms; they represent terminal products or resting stages in the evolution of matter. It is at once evident how useful such "breaks" in the continual flow of the energy of the universe would be for the safe operation of the physical-chemical machinery of life. They constitute landings or pauses in the stair-steps of evolution in which the requisite organization for the next step could be developed.

(5) The discussion in the preceding paragraphs viewed from a still greater distance manifests familiarity of another sort. We see that in the whole atomic-superatomic (or evolutionary) series there is a persistent reciprocal relation recurring at each level in the series between the atom in question and its environment. We see that in order that a given atom may be formed or exist, its environment must be fit. But this is the integrated relation between the survival of the fittest and the fitness of the environment pointed out by L. J. Henderson as holding for organic evolution. Consequently, the environment suitably conceived becomes an indispensable party to the development of a superatom of the next higher order. After it has come into existence, this environment supports and sustains the integrity of the superatom.

If we begin with the chemical atom, we find it existing in a given state in a given energy field. When we begin to organize these atoms into superatoms, we find that they too require a suitable energy field for their formation and existence. Each time we step up the complexity of the superatom we have to organize the environment to a higher level also in order to realize the new step.

This principle is the most sweeping generalization developed in this paper, and if true provides for continuous series of atoms and superatoms all the way from the electrons or the simplest chemical atom to the solar system and perhaps even larger organizations of astronomical bodies and formulates at least one generalization common to them all.

In conclusion, it should be said that

one thing stands out clearly in the mind of the writer. He is fully aware that he has seen some things "through a glass darkly" that others are able to see "face to face." This is always true in any such pioneering synthesis as this paper represents, and it is to be hoped that the reader who has read so far has been as much diverted by his own superior knowledge of some of the matters under discussion as by anything that he has read. Unless the writer is mistaken, the main part of this essay deals with matters that are obvious, *i.e.,* are intuitively known to many. The writer, however, believes that they ought to be said because in the saying they become tangible landmarks of future progress.

Biologists of every sort, including the applied biologists of medicine, are frankly hopeful for the elucidation of their most perplexing problems through developments in the field of chemistry. It now appears that they can help materially by working with us, with their superior experience in morphological concepts, and by helping us to select and purify the atomic-superatomic systems in this field of neglected dimensions. There seems to be no doubt, if we can break this virgin field to the plow, that an abundant crop will be obtained.

THE RAMAN EFFECT

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IN March, 1928, Professor C. V. Raman, of the University of Calcutta, announced the discovery of a new type of scattering of light observed in various liquids and gases. The study of this mode of light scattering by molecules bids fair to become one of the most powerful tools of the chemist and physicist for the investigation of molecular structure. The type of information concerning the internal structure of molecules revealed by these experiments could heretofore be gotten only by studying the absorption (or emission) of light in the infra-red region of the spectrum. This discovery by Professor Raman makes it possible to carry out the same study in the visible region of the spectrum. This is a tremendous advantage because the spectroscopic technique is very much easier and is much further developed in the visible region than in the infra-red. Professor Raman has studied the phenomenon of light scattering for many years, and his recent discovery is no doubt epoch making and compares in scientific importance to the discovery of X-ray scattering by A. H. Compton, of the University of Chicago, for which Professor Compton received the Nobel prize.

The object of this article is to present the subject of light scattering and to show the relation of the Raman effect to other phenomena which have to do with the interaction of light and matter.

FLUORESCENCE

The phenomena of the scattering of radiation by matter has been studied by physicists and chemists for a long time. Every one is acquainted with the facts that certain dyes show fluorescence under the proper conditions. If a little of the dyestuff "fluorescein" is dissolved in water made alkaline and the color of the solution is noted by holding the test-tube up to the window it is seen that the solution has a yellow color. If the observer now turns around he will note a greenish shade. In the first instance, the solution was observed by transmitted sunlight and in the second case the effect of scattered sunlight was observed.

The explanation of this phenomenon is as follows. The molecules of the dyestuff have the property of absorbing certain colors from the sunlight, which is composed of all the colors of the spectrum. Those colors that are not absorbed by the dyestuff are of course transmitted by the solution and they were observed in the first experiment described above. In the second experiment the colors that were scattered by the molecules of the fluorescein were observed. This explanation is given in the most general terms and the case must now be restated in terms of the theory of the constitution of light and matter as held at present by physicists and chemists.

THE NATURE OF LIGHT

It is quite impossible to describe here in detail all the phenomena regarding light which have finally led to the modern concepts of the theory of radiation. However, it is well known that there exist two rival concepts of the nature of light. On the one hand, the electromagnetic theory of the nineteenth century considered light to be an electrical phenomenon in the nature of a transverse vibration in the light-carrying medium, the ether. Such phenomena as inter-

ference of light waves, their diffraction on small objects (small holes, needles, edges, etc.) could very completely be described on the view that light is some kind of disturbance propagated as waves in a medium. However, other observations by physicists, such as the photoelectric effect, the Compton effect and the Raman effect, were difficult to understand on the basis of a theory that proposed light as a wave phenomenon. To explain these effects a new theory of radiation was invented. It is called the quantum theory of light because it proposes to consider a beam of light leaving its source as a stream of small entities called quanta. It is seen that the quantum theory of light is quite analogous to the corpuscular theory held by Sir Isaac Newton. However, it is believed now that these modern light quanta have quite a different set of properties from Newton's corpuscles. This is of course because a little more is known about the behavior of light and its interaction with matter than Sir Isaac knew. Of course light of the seventeenth century is probably the same as the radiation observed now, only our knowledge has changed and therefore our point of view and so our theories. In order to explain the observation of the physical world about us, human reasoning endows light quanta with just the properties they ought to have so that they could produce the effects as actually observed. And so there is associated with each light quantum a certain amount of energy and also momentum and a certain velocity, just as similar concepts are associated with a bullet or a cannon-ball. Should any one observe to-morrow some new phenomenon regarding light which would be quite inexplicable on the present ideas regarding radiation, it would be necessary to improve or change our concepts until such a view had been adopted as to the nature of light as would allow us to "explain" the new phenomenon.

If one now thinks about a certain beam of monochromatic light, say red light, there exists then the possibility of considering it as a vibration in the ether of a certain frequency, or one may think of it as made up of quanta of red light of a certain energy traveling through space with a certain velocity. Clearly the light is the same and the difference is simply due to the two different ways of calling it names. Evidently there must be a connection between the two modes of thought concerning the same thing, and Einstein has given such a relation between the energy E and the frequency ν of a light quantum:

$$E = h\nu$$

h = Planck's constant and it may be thought of as a proportionality constant. It is seen then that a quantum of red light (which has a smaller frequency) has less energy than has a quantum of blue light, which has a higher frequency. And since the frequency ν of a vibration and the associated wave-length λ are related to the velocity c of the undulation by

$$\nu\lambda = C$$

it is seen that a longer wave-length is connected with less energy. If for instance a blue light quantum be converted by any process whatsoever into a red light quantum then some energy had to be given to some other body because the resultant red quantum has less energy than had the initial blue quantum. This reasoning involves the principle of the conservation of energy. The relation just established between the energies and the frequencies (or colors) of light quanta is all important in our future considerations.

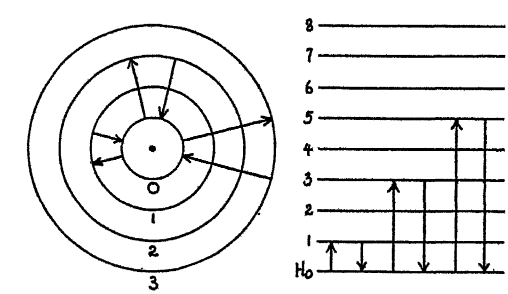
Absorption and Emission of Light

The process of absorption and emission of light can now be described very simply. The first fact of experiment to note is the observation that all materials

show specific absorption and emission of light. This means that a given kind of matter will only absorb or emit certain colored lights. The theory which explains these observations has been developed by N. Bohr on the basis of the electrical constitution of matter. A hydrogen atom which consists of a positively charged nucleus and an electron can absorb a series of light quanta of very definite frequencies and no others. The process can be expressed very concisely by means of equations such as the chemist uses for writing his chemical reactions:

$$H_0 + h\nu_{01} \leftrightarrows H_1$$
$$H_0 + h\nu_{02} \leftrightarrows H_2$$
$$\text{- - - - - - - - - - - -}$$
$$\text{- - - - - - - - - - - -}$$

The process of combination of the normal hydrogen atom, H_0 and $h\nu_{01}$ is of course the process of absorption and leads to the formation of an excited hydrogen atom H_1, H_2, etc., depending on the kind of quantum absorbed. It is seen that the reverse reaction (the equation read from right to left) is the decomposition of an excited hydrogen atom and this process constitutes the emission of a quantum and therefore the production of light. The various excited states of hydrogen are called higher energy states of hydrogen because the atom has more internal energy, and it is supposed that the electron resides in various energy levels depending on the amount of excitation. The situation is pictured graphically in Fig. 1.



Energy-Levels.
FIG. 1

The various energy levels of an atom are related in magnitude by a simple system of whole numbers called the quantum numbers. Atoms can exist in the various electronically excited states just described, and they have no other possibility of absorbing energy within their structure, whereas molecules may absorb energy in three different ways. They may be electronically excited as the atoms or they may take up internal energy in the form of increased vibration of their component parts. It is found that the vibrational states of a molecule are also related to one another in the order of small numbers. The third way by which molecules can take up external energy increases the rotational energy of the molecular system. The notion that a molecule can take up energy in the three ways just stated is of course purely a guess.

No one has seen an electron "displaced" to a "higher orbit" or a molecule "vibrating" or "rotating" in a "higher quantum state." However, such a guess or theory can be compared with experimental facts known about light (*i.e.*, energy) absorption of molecules, and if the deductions of such a theory compare favorably with the experimental findings, then it is said that there exists a satisfactory theory.

The dual nature of light as a wave and quantum phenomenon and the arbitrary nature of quantum numbers are now explained in a more satisfactory manner by the newer theory of atomic structure called wave mechanics. It is not only assumed that light has a dual nature but that particles (electrons, for instance) have also some of the properties ascribed to waves. All the problems which have to do with the scattering of light by matter can be stated in terms of these newer theories. However, it appears that the quantum view is sufficiently clear to

present an insight into the effects to be discussed here, although certain aspects of these phenomena can best be understood on the basis of wave mechanics.

The Tyndall Effect

The simplest kind of scattering process is the interaction between a particle or molecule and light quanta whereby neither of them is changed in nature or energy content. However, the direction of the scattered quantum may differ from that of the incident light. This simple case of scattering is observed every time a sunbeam plays with the dust particles in a darkened room and makes them visible. The effect is known as Tyndall scattering. The scattering process (in the case of molecules not at absolute zero) may be portrayed in a simple way by means of the equation:

$$M_0 + h\nu \rightarrow M_0 + h\nu_\theta$$

where $h\nu_\theta$ is an incident quantum; M_0 is the particle or molecule in the normal state, and $h\nu_\theta$ is the quantum scattered in a direction making the angle θ with the incident beam. Usually one observes such scattering effects at right angles to the incident beam. It is to be noted that the frequency or color of the incident and the scattered quantum are the same.

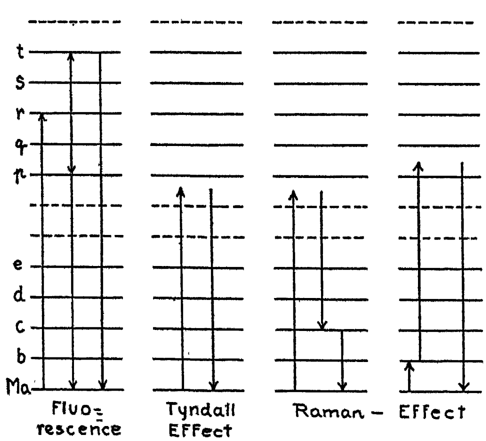


Fig. 2

The Case of Fluorescence

The simple experiment cited in the introduction can now be explained as follows. When a molecule of fluorescein shows the phenomenon of fluorescence it undergoes the following changes.

First, the incident light is absorbed by the molecule and it is thereby excited or placed into a higher energy level. It may well be that in the general case some electron is lifted into a higher quantum state and at the same time certain portions of the molecule vibrate relative to one another, and the molecule rotates, with more energy than in the normal state.

$$M_a + h\nu_{ar} \rightarrow M_r$$

is a shorthand statement of the absorption act, or we may refer to Fig. 2 and consider the molecule now in a higher energy level (M_r).

Second, if the molecule would now return to the normal state with the emission of the same quantum of light (the same color or frequency) then the act of emission of light, in this case, resonance, would have taken place. This case has already been discussed above. It is, however, conceivable that the excited molecule of fluorescein may make an impact with the solvent molecules or another fluorescein while it is still in the excited state. If it is now supposed that the excited molecule loses, during the impact, a part of its excitation energy to the other molecule (as kinetic energy, for instance) then it would be brought to a lower energy level (Fig. 2.).

$$M_r \rightarrow M_p + \text{Kin. Energy}$$

Third; it is seen that the excited molecule has now a smaller energy content and if it should now return to the normal state by emitting the quantum ($h\nu_{ap}$) corresponding to the state M_p then the emitted light is a quantum of smaller energy and the scattered light would necessarily be of a color towards

the red end of the spectrum when compared with the incident quantum:

$$M_p \rightarrow M_a + h\,\nu_{ap}$$

It is a fact that the fluorescent light is in most cases of a color on the red side of the exciting or absorbed light, and so the picture drawn above does explain this fact of observation.

But not all fluorescent light is located on the red side of the exciting light! Some cases are known where the color of the scattered quantum is on the violet side of the absorbed light. How can this situation be understood? It is only necessary to assume that a molecule in the excited state can not only lose but also gain energy during an impact with another molecule. It is then seen that the emitted quantum can have more energy than the absorbed one:

$$M_r + K.\,E. \rightarrow M_t$$

which act is followed by

$$M_t \rightarrow M_a + h\,\nu_{at}$$

Or it may be supposed that a few molecules have been brought to a higher excited state by temperature distribution. If these absorb the incoming light they may be brought to the excited state M_t. As before "an anti-Stokes line" would result in emission.

The fluorescent light ($h\,\nu_{at}$) which has a color towards the violet end of the spectrum when compared with the incident or absorbed light is known by the name of anti-Stokes light because Stokes, an English physicist, first put forward these considerations. It is seen that this reasoning applies the law of conservation of energy to the process under discussion.

Another conceivable mechanism is the following. It may be supposed that the excited molecule has a great probability of emitting a quantum of small energy (an infra-red quantum perhaps).

This act of light emission would bring the molecule to a lower quantum state. A second act of emission would bring the molecule to the normal state:

Absorption: $M_a + h\,\nu_{ar} \rightarrow M_r$
Partial emission: $M_r \rightarrow M_p + h\,\nu_{pr}$
Fluorescence: $M_p \rightarrow M_a + h\,\nu_{ap}$

To explain the formation of anti-Stokes lines it would have to be supposed that the excited molecule (M_r) can absorb from the surrounding temperature bath some small quantum ($h\,\nu_{rt}$) and the mechanism would be:

Absorption: $M_a + h\,\nu_{ar} \rightarrow M_r$
Additional absorption: $M_r + h\,\nu_{rt} \rightarrow M_t$
Fluorescence: $M_t \rightarrow M_a + h\,\nu_{at}$

In an actual case it is probable that a complicated molecule has many possible energy levels and the fluorescent spectrum may be one of great complexity.

It must now be noted that in the Tyndall effect all wave-lengths of light are scattered though not to an equal extent, and a beam of sunlight has a bluer color after scattering. However, in the case of fluorescence it is seen that the molecules absorb only certain frequencies of the incident light and emit light of definite frequency depending upon their energy levels, that is, upon their constitution.

The Raman Effect

If a beam of light is of such a color that it does not correspond to one of the energy levels of the molecule by which it is scattered, it would be expected that only Tyndall scattering would occur. However, Smekal in 1923 proposed the idea that after all there may exist the possibility that the molecule may interact with the incoming quantum to a sufficient extent to abstract from the beam some energy and be thereby brought into a higher quantum state. It may well be that the probability of the occurrence of such an act is very small as compared with the probability of simple scattering (Tyndall effect). This phenomenon has actually been observed by Professor Raman and constitutes the scattering process now known as the Raman effect. The Raman effect may then be considered as a Tyndall effect with complications. The complication is the reduction

of the energy of the quantum caused by the fact that the molecule is raised to a higher energy state. This interaction can take place between light of any color and absorption in the ordinary sense need not take place. The phenomenon may be described by the equation:

$$M_a + h\nu_0 \rightarrow h\nu_1 + M_c$$

where now

$$h\nu_0 - h\nu_1 = E_c - E_a = h\nu_{ac}$$

where E_c and E_a are the energies of the molecule in some excited and the normal state respectively and ν_{ac} is the frequency of light which would bring the molecule into the excited state M_c from the normal state M_a by absorption.

The scattered light would have a frequency ν_1 displaced towards the red of the spectrum when compared with the incident quantum ν_0. The displaced lines observed on a photographic plate are called the Raman lines. The difference $(\nu_1 - \nu_0)$ between these and the lines ν_0 produced by Tyndall scattering must be connected with the energy level system of the scattering molecule. In this way it is seen that the study of the Raman effect can give valuable information concerning the constitution (energy levels) of molecules!

It is natural to consider next the possibility of the interaction of a quantum ν_0 with a molecule which is already in an excited state due most likely to temperature distribution. In this case it may happen that the molecule may give to the incoming quantum its excitation energy and return to a lower energy state, perhaps the normal state. This case is quite analogous to the situation discussed under fluorescence. This action can be described conveniently by the equations:

$$M_a + \text{Kin. Energy} \rightarrow M_b$$
$$M_b + h\nu_0 \rightarrow M_a + h\nu_2$$

and

$$h\nu_2 - h\nu_0 = E_b - E_a = h\nu_{ab}$$

The corresponding Raman line would be formed on a spectrum plate on the violet side of the Tyndall line. It would be an anti-Stokes line, and such lines are actually found in the Raman spectra of many substances.

The difference between fluorescence and Raman effect is then the following. In fluorescence the incoming quantum is absorbed and corresponds to one of the energy levels of the molecule. Similarly the fluorescent light is related to the energy states of the molecule. In the Raman effect the incoming light is not an absorption frequency of the scattering system, nor is the scattered quantum related to the energy diagram of the molecule. However, the difference between them is related to the energy levels of the scattering molecule, and in certain cases it is true that this difference corresponds to an absorption frequency in the infra-red. In general a Raman line will occur between levels that combine with a third level.

This deduction is a result of wave mechanics. The Raman spectra studied so far have been correlated to the vibrational and rotational changes in the molecules and for this reason are of great importance to chemistry.

The Raman Effect and Molecular Structure

The group of substances known as hydrocarbons consist of carbon and hydrogen only and they contain the $\equiv C-H$ grouping. The vibrations of these two atoms relative to one another can be changed by absorption of light in the infra-red. Similarly a hydrocarbon molecule will emit infra-red radiation if it should change from a higher to a lower vibrational state. This type of spectrum can be observed in the Raman effect and the experiments are usually carried out by the use of the various visible lines of the mercury arc, the scattered Raman radiation being observed

at right angles to the incident light. In this manner the chemist can obtain a knowledge of the forces and binding energies holding the various atoms and groups of atoms together, and he can make his observations in the visible spectrum rather than in the infra-red, where experimentation is most difficult. Many groupings of atoms such as C – C, C – H, C = O, C ≡ N, NO_2, CH_2, CCl, HCl, NH, NO_3, CO_3, etc., have already been studied, and it is clear that many investigations of this type will be carried out in the near future which will result in a great increase of knowledge regarding molecular constitution. Since the discovery of the effect in 1928 already over two hundred scientific papers have been published on the subject.[1]

There are many features regarding the Raman effect which are of the greatest interest especially to physicists which have not been dealt with in this discussion for the reason that they would complicate the presentation and destroy the clearness which it is hoped has been attained.

It is thought that the method of representing the various processes involving quanta and molecules by means of equations is very useful. One more scattering process to be represented in a simple way by such an equation is the Compton effect, which has a great analogy to the Raman effect. It will be remembered that in this case a quantum of high frequency (X-rays) interacts with an electron of a scattering material. The quantum is thereby changed in frequency and momentum, the electron is dislodged from the scattering substance and gains energy and momentum:

$$E_0 + h\,\nu_0 \rightarrow E_{fast} + h\,\nu_1$$

where E_0 is the low energy electron as residing in the scatterer; E_{fast} is the dislodged fast electron, $h\,\nu_0$ and $h\,\nu_1$ are the initial and scattered X-ray quanta.

One more point of interest in this connection is the fact that the use of these equations leads to a clear understanding of the relation of some of the processes involved. If the Raman effect resulting in a quantum of lower frequency is considered it is seen that the reverse of this reaction leads at once to the prediction that anti-Stokes lines should also be possible, for it is a result of thermodynamics that for each elementary process there should exist a corresponding reverse process. This principle has been called variously the principle of entire equilibrium, of detailed balancing or of microscopic reversibility.

[1] Comprehensive scientific articles are: (1) A. S. Genesan and S. Venkateswaran, "A Memoir on the Raman Effect," *Ind. Jl. Phys.*, 4: 195, 1929; (2) "Molecular Spectra and Molecular Structure," *Trans. Faraday Soc.*, September, 1929; (3) A. Dadieu and K. W. F. Kohlrausch, "The Raman Effect in Chemistry," *Berichte*, 63: 251, 1930; (4) C. Schaefer and F. Matossi, "The Raman Effect," *Fortschritte der Chemie*, etc., 20, No. 6, 1930.

AN INDIAN SOCIAL EXPERIMENT AND SOME OF ITS LESSONS

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When social engineers come into their own as custodians of the collective welfare, cultural anthropologists believe that they will find descriptions and analyses of experiments in collectivism by the less civilized peoples of very considerable benefit. Or rather, they will probably have studied them in preparing for the degree in social management. It is true that the conditions under which such experiments were made were quite different from our own but the minds that had to grapple with them were essentially the same. To the study of one primitive social and governmental experiment of this sort, that undertaken or evolved by the Creek Indians who formerly occupied most of the territory of the present states of Georgia and Alabama, I invite your attention.

North of Mexico the confederate organization of the Creek Indians was surpassed in ingenuity and completeness only by that of the Iroquois, though the names of none of the geniuses who contributed to its construction, the counterparts of the Iroquois legislators Dekanawida and Hiawatha, have come down to us. This probably means that it was a complex, slower in growth and more natural than the one so successfully launched by the northern Indians.

The higher tribal organizations found in America rested on a type of farming which has been called milpa agriculture. The principal exceptions seem to have been on the Western plains where peoples were held together by the communal bison hunt, and on the north Pacific coast where immense natural food supplies were to be found on a narrow strip of territory and where a property-competition pattern brought people together annually in towns of considerable size. But even here governments were practically confined to single towns.

The main crops of the Creek Indians, as of the other agricultural tribes of North America above Mexico, were corn, beans and pumpkins, though small amounts of tobacco were also grown and occasionally sunflowers. Corn was their staple among vegetable foods, occupying much the position of wheat in the Old World. It was raised both by individuals—usually old women, in small scattered plots—and in large communal fields, one of which was planted and cultivated by the men and women of each town working together. This last was divided into sections for the separate families by narrow strips of grass, but all labor except some of the harvesting was in common. A certain portion of every crop went into a town granary in charge of the chief for use on occasions of common concern, such as ceremonies, the entertainment of emissaries from other tribes and the relief of families reduced to want by unforeseen misfortunes. It is probable that this system of cultivation was introduced into the Gulf region along with corn itself, and it is interesting to speculate whether the more closely knit social organizations which we find in the corn area were due more to the corn or to the communal method of caring for it.

The weakness of Creek economics—and this was true of all other agricultural tribes north of Mexico—lay in the related facts that they had no domestic animals except the dog and made practically no use of fertilizer. It is rather

singular that the only references to fertilizer come from certain loosely organized fishing peoples of the north Atlantic coast who are said to have put fish and seaweed in their corn-hills, but there is no evidence of its use by any of the Gulf tribes before European contact. This of course meant periodical exhaustion of the fields except in a few favored sections, an exhaustion all the more frequent because of the shallow cultivation which the rude native implements rendered necessary. This and the depletion of supplies of firewood made removal of the entire town from time to time a convenience if not a necessity. We know of some towns which existed in approximately the same situations for two or three hundred years, but this means that the same general position was maintained and in point of fact there was often considerable shifting within a given area.

In any case periodic desertion of the town was universal during the hunting season. The dog was rarely eaten, never used as a draft-animal and probably not employed in hunting. Although bison formerly existed in considerable numbers in the territory of our present Gulf states, the deer seems always to have been the main source of flesh food, and deer hunting involved the abandonment of the regular towns twice annually. Moreover, although deer drives were occasionally resorted to, most hunting was undertaken by single families or small groups of families, and this fact tended to break up the solidarity of the tribe. Bear were usually hunted by small groups also, but we encounter a community device in the shape of a "bear park," a tabued territory reserved for the town as a whole and visited at fixed periods.

Fish were taken by individuals or by groups. Collective fishing was confined to the dry season when some streams had shrunk to detached pools which could be poisoned or dragged, and was participated in by an entire town or neighborhood.

As so often happens, the ceremonials furnish an excellent index of the tribal economic foundations, and the most important of all was the great "busk" or "green corn dance," as it is popularly called by whites, celebrated in July or August when the first flour corn was ready to eat. In the more ancient ceremonies four ears of corn were brought into the ceremonial ground and laid beside the four main sticks of the sacred fire. This was always done, but occasionally a piece of meat or four fish were added, showing the importance, but at the same time the secondary importance, of flesh food.

Here, then, we have certain factors—agriculture and communal fields, expressing themselves in common ceremonials, group fishing, bear parks, occasional bear drives—tending to encourage a stable town life, an increase in population and community feeling; and certain others—no domestic animals of economic importance, no use of fertilizer, periodic separation to obtain meat—exerting an influence in the opposite direction. We should expect in consequence a social organism more closely knit than would be the case with a purely hunting or food-gathering people but one not as firmly bound together as in regions where there were no such disabilities. In fact, we do find our expectations realized in a general way, but we also discover that it is impossible to predict a set social expression from a given economic condition. Without going outside of the Southeast, we find quite diverse social and governmental systems erected upon an economic base practically identical with that which has been described. The Natchez constituted a theocratic absolutism, or rather oligarchy, the oligarchy being exogamous and perpetuated in the female line. The Chitimacha of Louisiana and the Timucua of Florida were

also governed by oligarchic groups, but these were endogamous, *i.e.*, true castes. The Choctaw, though raising much more corn than the Creeks, had a weaker central government, less inequality between chiefs and people, and a poorly developed social and ceremonial system. The Chicasaw were intermediate in many ways between Creeks and Choctaw but were more closely knit internally and more perfectly organized for war. The Cherokee were a loose confederation of related towns which seem to have had a kind of ceremonial capital but no civil capital, leadership being vested in the heads of the seven social groups or clans of which it was composed. The Yuchi were the only tribe in the entire region which had what we might call "societies," and upon the two into which they were divided rested leadership in civil and military affairs, respectively. Some of the Siouan tribes of the Piedmont section were little dictatorships, and among them a primitive form of trade and manufacture had begun to affect the economic and social structure. A little farther east, in the tidewater sections of Virginia and North Carolina, trade and the manufacture of a kind of shell money seem to have paved the way for sporadic "empires" like those of Wingina and Powhatan, which were in part probably a reflection of the pressure exerted by inland peoples. In spots along the Atlantic and Gulf coasts and in favored places between the larger tribes were lodged small bodies of Indians, often made up of refugees or outlaws, which were of a democratic complexion, as might have been anticipated. Among the Atakapa of southwestern Louisiana and Texas this type of organization was normal and in this instance may well be coupled with the fact that they raised little or no corn. In an interesting note one of our early informants tells us that there were to be found near the Choctaw gipsy-like bands who followed the herds of bison from place to place and lived in a very rude manner.

This brings us to a consideration of another set of factors—genetic relations and associations based upon them. These are operant perforce among all people, but are more conspicuous in primitive societies than in our own. Hewitt considers them to have been more powerful than any others in cementing the League of the Iroquois, but they were almost equally in evidence in the Creek Confederation, and were at work in the evolution of every little Indian commonwealth.

Through relationship, real or imagined, a Creek was bound first to his own clan, next to several other clans, next to the tribe and finally to other tribes. The Creek clan was a body of supposedly related people usually bearing the name of some animal. Not long ago a considerable school of students of primitive society held that group or clan relationships were chronologically prior to family relationships, but nearly all American ethnologists believe rather that the family idea has been extended to the clan. However that may be, the fact remains that a Creek stretched the terms for mother, maternal uncle, brother, sister, nephew and niece over most of the clan to which he belonged, and the terms for father, paternal aunt, son and daughter, as also brother and sister, over most of his father's clan. There was absolute prohibition of marriage in the mother's clan and blood relatives in the father's clan, and a distinct opposition to marriage in the father's clan in its entirety; but the sense of relationship went still further, for there was a special designation for the clan of the father's father. Moreover, the clan of each parent was often one of a group to which the same exogamous laws applied so that, for instance, a man who belonged to the Alligator clan could marry neither a woman of the Alligator clan nor one of the Turkey clan. Some of these linkages, like the one mentioned, held throughout the entire Creek nation, but in many of

the fifty towns of which it anciently consisted there were special groupings of clans proper to that town or to a small number of them. These were brought about by the institution of clan councils, associations of clans under the leadership of the oldest or most influential male belonging to it, its "uncle" in an eminent sense. They usually included members of clans considered to be related throughout the nation, but if there were a few members of a certain clan in one town having no natural affiliations they would unite with some one of the existing councils, and usually the children of this clan would consider the other children connected with the council as brothers and sisters with whom they would on no account marry.

The above description applies to the later years of the confederation. At an earlier period, if we are to believe many native informants, there was still another complication. All the clans of each town are ranged into two sections or "moieties" called Hathagalgi or "Whites," and Tcilokogalgi, "People of a different speech," which we will call Hathagas and Tcilokis for short, substituting the English plural for the Creek. These are well-known divisions which determine the alignment of the men in practice matches of the great Southeastern ball game, a form of lacrosse, the Hathagas opposing the Tcilokis. There is, however, a very strong tradition that these two moieties were once exogamous as such, that is, that a man belonging to any Hathaga clan could marry neither a woman of his own clan nor one of any other Hathaga clan, and similarly that a Tciloki could not marry a Tciloki. Again, the moieties were not made up of the same clans in every town so that further complications arose when a man or woman wanted to marry outside of his or her own village. Since marriage into the father's clan or the father's clan group was also frowned upon, and there were limitations of age and certain others to be mentioned presently, it is evident that the number of potential wives or husbands from whom a Creek might choose was relatively limited.

As the leading clans or groups of linked clans and the two moieties were represented throughout the Creek nation, a man belonging to one town should normally find some group in every other town which would recognize him as a brother, there would be others affiliated with the clan of his father and still others into which he might marry. If his clan or its equivalent was wanting in a town which he happened to visit, he was almost certain to find one corresponding to that of his father or grandfather, and his own position would be oriented by reference to these. For instance, the Bear clan might be represented in two towns, one of which might also have a Deer clan but no Raccoon and the other a Raccoon clan but no Deer. A man of the Bear clan moving from the first to the second would find his own people and he would take up, along with them, the attitudes they had established toward the Raccoon clan, although that clan was wanting in his own native settlement. If he belonged to the Deer clan, however, he would naturally transfer to his new associations the attitudes toward the Bear clan which he had already established, and the attitudes of the Bear people in his adopted town toward the Raccoon would tend to determine his own attitudes toward them. It is easy to see how important a knowledge of genealogy was for officers of the Creek towns entrusted with the perpetuation of the collective institutions, and we know in fact that prospective marriages were often the occasion for long and serious deliberations.

We must now consider intertribal manifestations of this relationship system. The numbers of a tribe might be increased by voluntary settlers, but the greater part of those who came in as

individuals were captives. Under the conditions of Indian warfare the most merciful tribe was apt to survive because it made up its losses more rapidly than a tribe which systematically killed all prisoners, and the larger and more successful tribes were most noted in this respect. Hewitt tells of one occasion on which the Iroquois instructed a small people that had come to live with them as to the importance of preserving captives alive. Upon the whole, however, it does not seem probable that the Iroquois and Creek confederations excelled because of the number of individual captives which they incorporated but because of the fact that they had established a technique for the admission of entire bands and small tribal remnants. The nature of this and its assumed origin is given in a Creek story of which the following is an abstract.

The Coweta and Kasihta, the two most important Eastern bands of the original Creek stock, moved into their territories from the West, accompanied it is claimed by one or two others. If there were others, however, they were left behind by these two which continued their conquering career as far as the Atlantic Ocean. At last there were no opponents left, and, wearied of inaction, they held a council to determine what was to be done. After long deliberation it was decided that, as a "moral equivalent for war," the two peoples should meet periodically in encounters on the ball field. After this any town or tribe which established friendly relations with Coweta could become a part of the confederation and would play on the Coweta side, and a town establishing friendly relations with Kasihta was similarly allocated on the Kasihta side.

In course of time not only were a number of towns of the same speech gathered into the federal body in this manner, but people more distantly related, such as the Hitchiti, Alabama and Koasati, and finally peoples very remotely related or related not at all—the Natchez, Yuchi and one or two bands of Shawnee. In this last case, a position in the confederation was actually made for a foreign tribe since the greater part of the Shawnee were never connected with it and those who actually joined subsequently returned to the rest of their people.

The relations between the Creeks and another independent body, the Chickasaw, are equally instructive. Early in the eighteenth century a small band of Chickasaw settled near the British post at Augusta, Georgia, but later moved over into the Lower Creek country and established themselves near the town of the Kasihta. Later they returned to their own people, but the alliance which they had meantime formed persisted and applied to the entire Chickasaw nation, so that, in 1793, when war broke out between the Creeks and Chickasaw, the Kasihta refused to take up arms with the other Creeks and their right to act in this independent manner was never questioned. At a somewhat earlier period, when the French and Choctaw were pressing hard upon the Chickasaw, the latter debated removing *en masse* into the Creek country, and if they had done so they would undoubtedly have taken their place as a town of the same "fire" as Kasihta. Orators of some Creek towns went so far as to claim the white colonists of South Carolina for their division.

It is important to take note of the several sorts of attitudes established by the above associations. Kinship served as a point of departure of one series which extended, as has been described, not only to every one in the same town but potentially also to the inhabitants of other towns of the same tribe and finally to foreign tribes. A member of the Raccoon clan, on visiting the Chickasaw, would discover a Raccoon clan there and representatives of that clan would accept him as a brother and entertain

him as long as he chose to remain among them. A Creek who belonged to the Deer clan would find friends and relatives of this type not only among the Chickasaw but also among the Cherokee of the southern Appalachians and the Timucua of Florida. Had he strayed so far and had there been no war between the tribes, a man of the Bear or Wolf clan would undoubtedly have been entertained similarly by the Bear or Wolf people of the Mohawk of New York, the Chippewa of the Great Lakes or even the Tlingit of Alaska. And, although I know of no specific cases, I think it evident that members of clans not directly represented in many of these tribes would have discovered indirect connections through which they would have found some means of allocation in the foreign group.

This does not mean that clan connection completely effaced national, racial or linguistic differences, any more than does our modern freemasonry, which in some ways it resembled. Even within the Creek nation itself the influence of clan connection was seriously modified by the dual town system already descibed. In fact, social communion and marriage were distinctly encouraged within the same town divisions, while contact with or marriage among those of the opposing town group was as distinctly discouraged. In other words, side by side with clan and clan-group exogamy we have town endogamy. The latter distinctly modified the former.

Again, there was a definite though varying attitude between towns of diverse language and culture although belonging to the same division. There was less likelihood that a man of the dominant tribe, the Muskogee, would marry a woman belonging to an incorporated tribe than that he would marry one of his own though of a different town, and he was less likely to marry a Yuchi or Shawnee than some one from the cognate Hitchiti or Alabama. The feeling was not, however, one of superiority but of diversity in character and feeling. A Muskogee would poke fun at the, to him, queer customs of a Hitchiti, an Alabama, or a Yuchi, and laugh at his speech, but he did not hesitate to place a Hitchiti of merit over the entire nation, he followed an Alabama to war and he had a wholesome respect for the Yuchi. And of course aversion to tribes which were entirely dependent was much more intense. Since, when two tribes went to war, intermarried members of both were apt to be the first sufferers, there was so much less incentive to foreign matches.

There were thus two Creek institutions which tended to preserve peace with other tribes and increase the federal body. One of these, the clan system, was shared with various peoples of America and indeed of the world. It was able to function well only in areas occupied by tribes having a similar clan system, but where the naming of clans was of another character it could operate only with difficulty. Thus, kinship would help a man of the Bird clan among the Cherokee, Timucua and Chickasaw, but not among the Choctaw, who had practically no clans named from animals. The institution of town moieties and a tribal adoption system, on the other hand, was, if we except the Iroquois and some peoples related to them, specifically Creek. It was this which built up their confederacy into a formidable defensive and offensive organization and gave it its conspicuous place in our early history.

Having examined the Creek state on its conservative side, we must now look at the factors which tended to keep it separate from other peoples and inculcate an unfriendly attitude toward them. In the first place, one of the two clan moieties of which mention has been made, the Tciloki, was concerned with war, the Whites, as might have been anticipated, having a similar association with peace. With the former was also

linked one of the two town divisions, the "red towns," and with the latter the opposing division or "white towns." This merely means that the red clans and red towns had official charge of matters concerned with war, not that they alone went to war. The chiefs (mikos) and second men (henihas) who occupied the principal civil positions were in some measure hereditarily determined since they were selected from definite clans, but war leaders seem to have been chosen on the basis of their demonstrated ability. The henihas, of whom mention has just been made, were either of the Wind clan or of some other white clan, and the mikos were oftener taken from white clans than from red ones. This was probably the rule in white towns. We also know that white towns were cities of refuge for enemies, and for murderers who had escaped from another settlement, though in the latter case the refuge was not necessarily a permanent one.

The fatal defect in the Creek organization as an instrument for preserving peace was the fact that social advancement depended largely on honors obtained in actions against an enemy. Success in hunting, in securing eagle feathers, in oratory and in another way to be mentioned shortly helped a man to rise in the esteem of his fellow citizens, but these were ineffective apart from war actions. It is not to be understood that what we here call war bore much resemblance to the institution with which white people are familiar. Rarely, and only incidentally, was a tribe destroyed or seriously injured in the course of such wars. They consisted merely of marauding expeditions by volunteer parties, which depended upon secrecy and surprise, were satisfied with a scalp or two, were quickly turned back by exposure or by an unfavorable omen and were considered failures if the lives of two or three men had been lost. The motivation of the whole system comes out clearly in the statement that an unsuccessful war party is known to have murdered members of their own tribe caught at some point remote from any settlement. The principal and perennial excuse for them—for war always demands such—was revenge for a past injury, though the Indian, like ourselves, simply conceived of it as "getting even." But of course neither side ever felt that it had attained this patriotic state of equilibrium and, as the powerful social impulse already mentioned never slept, peace was sporadic and rarely lasted long except where a tribe was admitted into the confederate body. Since this was not likely to happen in the case of large neighboring tribes like the Choctaw and Cherokee, war became increasingly bitter. Immediately after white contact it grew worse owing to the slave raiding expeditions instigated by the English colonists and entanglement in the mutual rivalries of the English, French and Spaniards. After American dominance had been established, however, Indian warfare no longer received encouragement and soon came to an end, whereupon the Indian population began to increase, imported epidemics having in the meantime spent themselves. This much our Indian wards may be said to owe us, though whether it was sufficient compensation for smallpox, tuberculosis, trachoma and alcoholism may well be doubted.

The warfare of attrition of which I have just spoken and the ever-present cloud of danger under which life must be conducted may be set down as constituting the outstanding defects in ancient Creek life, but it made up for this in freedom from that other black cloud of civilization which goes under the name of unemployment. Food, clothing and shelter were not inextricably united with the thing which we call a "job," nor were they given as charity. They were as much assumed as fresh air, water and sunlight. In the

latitude of the old Creek country clothing occasioned little worry. The articles of clothing were extremely simple; the raw material for them easily obtained, and they were durable. For food and shelter a man might rely always upon his fellow clansmen or, in a strange town, upon whoever had taken him under his protection. If no one did so, although this rarely happened, he was at liberty to sleep in the town house where during the winter a fire burned all night. So highly was hospitality esteemed that violation of it was one of the most heinous of all offences. Adair tells us that the Chickasaw characterized an inhospitable act by saying "the buzzard is at home," and that the application of this term was much dreaded.

Of course this meant that the more successful food-gatherers helped take care of those who were less successful and it will excite the disapproval of many good Americans with inherited bank balances, apprehensive for the safety of those twin deities of the industrial pantheon "individual initiative and energy." But a great deal of misconception of the workings of aboriginal hospitality has arisen owing to the nonconformity of primitive customs and modern life. I remember the case of an old woman on one of our Western reservations who received a sum of money from the agent on the first day of each month, whereupon her family connections promptly came to live with her and helped her to go through with it in half the time which it should have covered. Cases of this kind are numerous and are used as arguments not only against aboriginal institutions but against "socialistic" or "communistic" institutions generally on the ground that under them sloth is placed at a premium and industry at a discount. And perhaps the collectivist is moved to defend early man by pointing to these institutions as examples of mutual helpfulness and brotherly feeling.

But when we study the workings of hospitality under truly primitive conditions we find its detractors and its apologists both in error. In the old Creek Confederation each household was practically a self-supporting economic unit. The women manufactured the pots, baskets and clothing, and furnished the plant foods, except for such labor as was bestowed by men on the common fields. In addition to this last-mentioned work, men constructed the houses, made mortars and pestles for crushing grain, canoes, hunting and fishing implements and ceremonial objects, and furnished most of the animal foods and the raw material for skin clothing. A rude and temporary division of labor also existed between houses when individuals with different aptitudes exchanged the fruits of their industry instead of making all sorts of things for themselves, but production was so closely adjusted to consumption that there was no surplus except occasionally in the supplies of food. This, however, was ordinarily sent to less fortunate neighbors or dispensed in feasts, or in some of the regular ceremonials, though special hunting excursions were often undertaken in preparation for the last. Supplies were always laid up in the storehouse of each family and here it was possible to hoard, but the person who did so was regarded with utter contempt and was the object of general sarcasm and ridicule, not because such a man was felt to be a menace to the community but because he was regarded as a fool who chose to act contrary to his own best interests. For, in the first place, the surplus which he enjoyed one season might next year be converted into a deficiency, and who would then come to his assistance? In other words, generosity in the handling of food was of the nature of family insurance. But even if a family contained several extraordinarily good hunters and might look forward to continuous plenty with more assurance than their neighbors, it

was stupid of them to hoard since, by doing so, they not only attracted the ill will of the community but, unless they could make up for the defect by striking successes in war, they cut themselves off from those commanding positions in the tribe to which they might otherwise aspire. Attainment of leadership by "feeding the town" in time of want is the theme and moral of story after story repeated among Indians of the north Pacific coast. The agricultural life of the Creeks took away in some measure the importance and the peculiar opportunities of the hunter but they were still considerable and were probably greater before white contact. In short, in Creek society the distribution of surplus food was not merely ethical but for the interest of the owners of the surplus. Refusal to share it threatened their own future security and prevented them from advancing in the social scale—unless, of course, they could compensate by military exploits. It is significant that, along with our wide-spread popular recognition of Indian hospitality and generosity, we have preserved in the expression "Indian giver" a feeling that there was a string to all this, as was indeed the case.

But while a study of the economic and social system of the Creeks serves to destroy the myth that Indians were people of peculiar virtue, the system itself contains suggestions for the conduct of our own society that are not without value. It disproves at once the repeated assertion that a society that systematically feeds all its members can not be made to function. Creek society depended, and our own depends, on a pull and a push to make them operate. The pull upon which we rely is acquisitiveness and our push is starvation, while the pull of the Creeks was social position and popular esteem, and their push contempt and ridicule. Sociologists and political experts will do well to remember that this is no one's theory but the case of a working society. If we would approximate to it we must not only take government out of business but take money making out of it also.

From our review of the Creek Confederacy it appears that their manner of supporting life determined the nature of their organization only in its broadest outlines. In preserving the internal coherence of the state the most important single element was real and fictional consanguinity and affinity, but various tribes had been drawn into a supertribe by a special device involving the association of two sets of towns concerned with war and peace respectively with any of which outside units might become associated. Its major defect was in making war honors the principal stepping-stone to social advancement, so that the peace-promoting tendencies of the body taken as a whole were constantly nullified by the ambition of every male member of it. Alongside of this there existed a beneficent tendency to give social recognition to men who succored the community in time of want, but its good effect was destroyed by the emphasis placed upon man killing. However, in spite of the blight which the latter institution exercised, the well-being of every member of the state was its main concern, and all were fed, clothed and sheltered, the motive relied upon being common desire for insurance against unpredictable events, social esteem for the able and fear of ridicule for the sluggards.

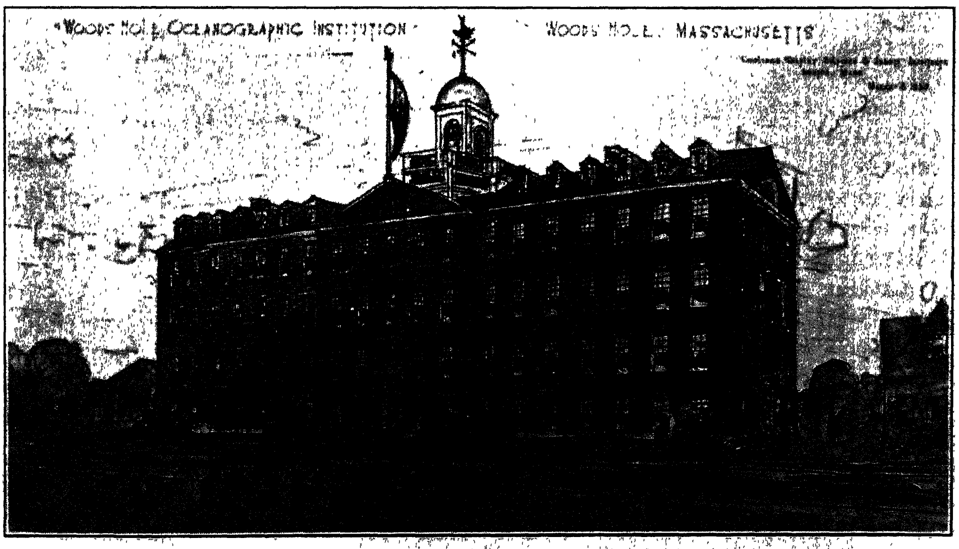
THE PROGRESS OF SCIENCE

THE WOODS HOLE OCEANOGRAPHIC INSTITUTION

In February of this year, upon the recommendation of the National Academy of Sciences that "the establishment and endowment of an Atlantic oceanographic institute should be realized at the earliest possible moment," the Rockefeller Foundation granted $1,000,000 to finance buildings and equipment, and $1,000,000 as a permanent endowment fund. Later it agreed also to give $50,000 a year over a period of ten years to form a special operating fund. Dr. Henry B. Bigelow, research curator in zoology at the Museum of Comparative Zoology of Harvard University, was appointed director.

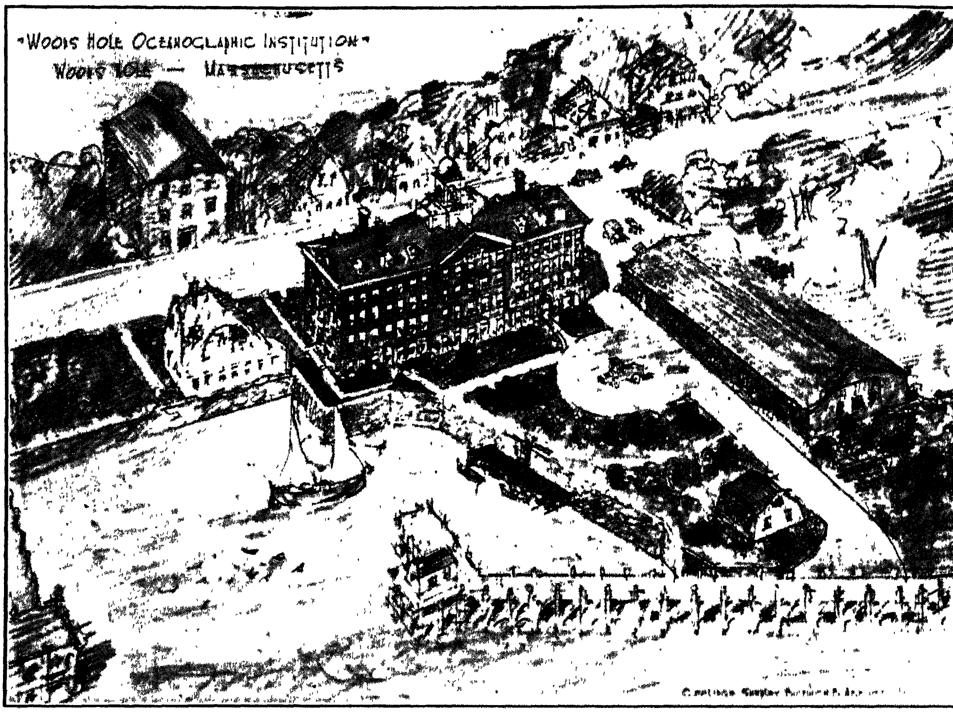
The purpose of the new institution, as its name implies, is to carry on and to encourage the study of the sea in the broadest sense. Like the Marine Biological Laboratory, it is an independent organization, but similarly assured of informal association with other educational and research institutions through the personnel of its trustees. The initial board is as follows: Dr. Thomas Barbour, Dr. Henry B. Bigelow (director), Dr. William Bowie, Dr. E. G. Conklin, Mr. Newcomb Carlton, Dr. Benjamin M. Duggar, Dr. Frank R. Lillie (president), Dr. John C. Merriam, Mr. Seward D. Prosser, Mr. Lawranson Riggs, Jr. (treasurer), Mr. Elihu Root, Jr., Dr. Harlow Shapley, Dr. T. Wayland Vaughan. The by-laws provide for an increase in the number of trustees up to twenty-four.

The choice of Woods Hole as the site for the headquarters of the new institution was reached only after a careful consideration of other possible situations along the Atlantic Coast of North America. The final decision was based on the combined advantage of close proximity to two world-famed laboratories of marine biology, on the one hand, and, on the other, on the exceptional opportunity for illustrative inves-



THE WOODS HOLE OCEANOGRAPHIC INSTITUTION

THE BUILDING IS NOW UNDER CONSTRUCTION AND WILL BE COMPLETED IN THE SPRING OF 1931.



THE OCEANOGRAPHIC INSTITUTION AS IT WILL APPEAR FROM THE HARBOR

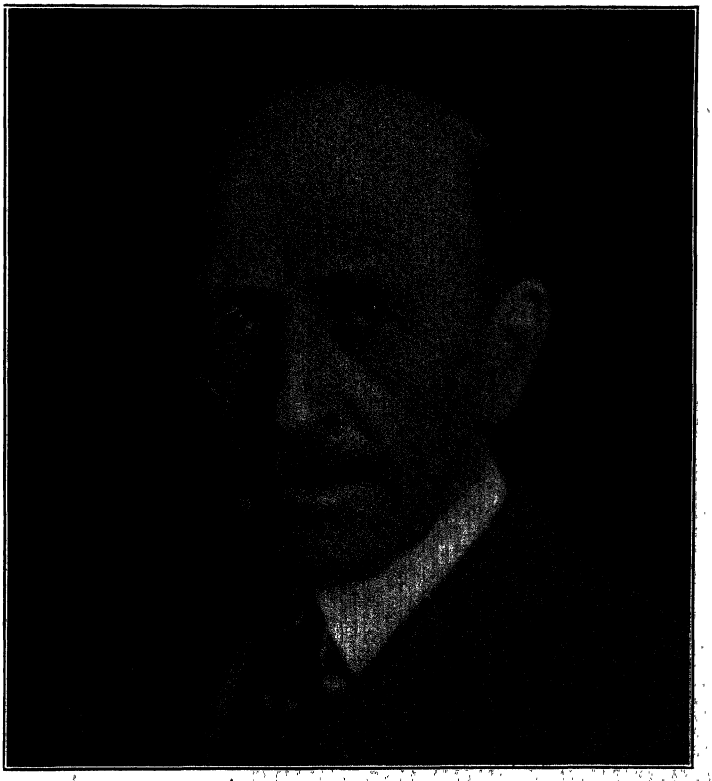
tigations that is offered by the neighboring waters.

The first of these inducements needs no explanation. The second depends in part upon the ease with which the transition from inshore to offshore waters can be reached from Woods Hole, on the abruptness of that transition and on proximity to the continental slope, and abyss. At the same time the Gulf of Maine, close at hand, with its tributaries, offers a more promising field for intensive investigations into the interaction between the physical-chemical and the biologic aspects of oceanography than any other sector of comparable extent along the coast of America.

The principal instrument of research will be the vessel which is as much a part of an oceanographic institution as a telescope is of an astronomical observatory. In fact, the whole institution centers around this boat which is to be the most modern of oceanographic vessels. Therefore a large sum of money is being spent on a floating laboratory. The plans for it have been completed and the contract for the work has been let. The ship which is being built in Copenhagen is 142 ft. long over all and 105 ft. at the water line; and its displacement will be about 380 tons. The vessel is to be a two-master with ketch rigging. An auxiliary Diesel engine will make it possible to cruise without sails, over a radius of several thousand miles. The vessel will contain two general laboratories, a chart room and about nine staterooms and the quarters for the crew of about thirteen, and a mess room. The Diesel engines run on crude oil, and there will be no gasoline on the boat. A catastrophe such as occurred in the case of the ill-fated *Carnegie* can not take place. The ship will be fully equipped with all the instruments used in oceanographic service. A drum with about five or six thousand fathoms of steel cable will be provided for dredging.

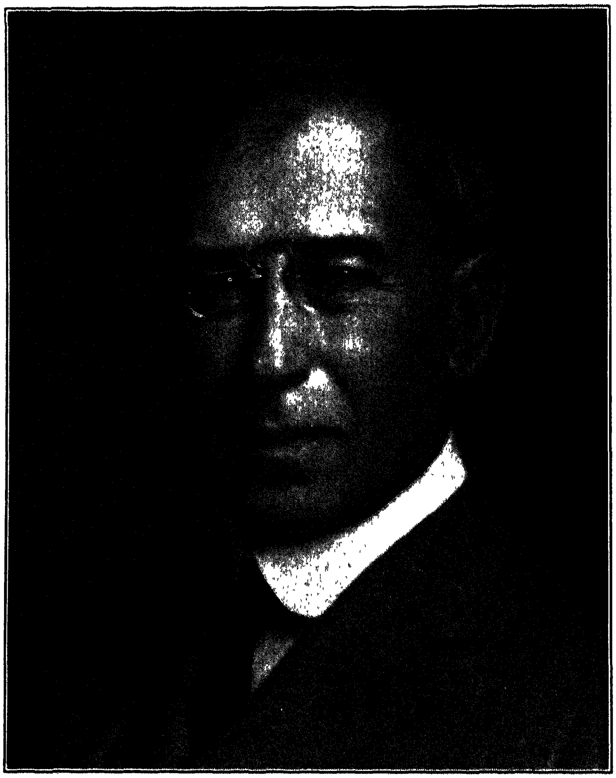
THE EIGHTIETH MEETING OF THE AMERICAN CHEMICAL SOCIETY

CINCINNATI, Ohio, was the science capital of the nation during the week of September 8, or at any rate the chemical capital, when some 2,000 chemists assembled for the eightieth meeting of the American Chemical Society. Convening under eighteen broad subdivisions of chemistry more than four hundred titles appeared on the program. Several symposia of significance were scheduled. One of these on industrial fermentation stressed the various phases of the employment of micro-organisms in chemical processes. Another symposium held jointly by the division of industrial and engineering chemistry, gas and fuel chemistry, and petroleum chemistry, was on industrial high pressure reactions, a subject of immediate industrial and research importance publicized extensively of late because of the success met by those working in the field of petroleum hydrogenation. The division of fertilizer chemistry presented a group of papers on the action of ammonium citrate on superphosphates, a topic of importance to those concerned with soil fertility and plant foods. Still another symposium was held by the division of medicinal chemistry



DR. WILLIAM McPHERSON

PRESIDENT OF THE AMERICAN CHEMICAL SOCIETY, WHO HAS BEEN A MEMBER OF THE STAFF OF OHIO STATE UNIVERSITY SINCE 1893 AND DEAN OF THE GRADUATE SCHOOL SINCE 1911. WHILE HIS PRINCIPAL INTERESTS HAVE BEEN IN CHEMICAL EDUCATION, HE HAS CARRIED ON RESEARCH ON THE HYDROXYAZO COMPOUNDS AND ON THE CONSTITUTION OF MANY ORGANIC COMPOUNDS, AND HAS BEEN ACTIVE IN THE ADVANCEMENT OF CHEMICAL EDUCATION.



DR. MOSES GOMBERG

PRESIDENT-ELECT OF THE AMERICAN CHEMICAL SOCIETY WHO WILL, ACCORDING TO THE PROCEDURE OF THE SOCIETY, BECOME ITS PRESIDENT FOR ONE YEAR, BEGINNING ON JANUARY 1, 1931. PROFESSOR GOMBERG IS THE CHAIRMAN OF THE DEPARTMENT OF CHEMISTRY AT THE UNIVERSITY OF MICHIGAN AND IS INTERNATIONALLY KNOWN FOR HIS WORK ON TRIVALENT CARBON AND FREE RADICALS, THOUGH THIS REPRESENTS BUT A PORTION OF HIS FUNDAMENTAL RESEARCH.

where endocrines was the subject. The qualifications of chemistry teachers resulted in active discussion in the division of chemical education, and non-aqueous solutions were of equal interest to research workers in the division of physical and inorganic chemistry. These symposia represented but a small fraction of the extensive program compiled with care by each of the divisions, and comprising topics of such interest that the leaders in chemistry attended in large numbers both to hear and to discuss.

There were divisional meetings on Wednesday and Thursday mornings, followed by luncheons at the University of Cincinnati. The president's address by Professor William McPherson, "Chemistry and Education," was given on Wednesday at 8:30 in the Emery Auditorium, following which there was a musical program.

On the afternoon of Thursday an inspection trip was made to the Cincinnati Water Works and there was a drive around the city in automobiles, starting from the university immediately after luncheon.

In the business sessions proposals for certain reorganization, the election of editors and the selection of further meeting places were considered. The eighty-first meeting of the society will be held in the spring of 1931 at Indianapolis, Indiana.—H. E. H.

BRONZE MEMORIAL PLAQUE, PICTURING MR. AND MRS. THOMAS A. EDISON, UNVEILED AT FORT MYERS, FLORIDA, IN CELEBRATION OF MR. EDISON'S EIGHTY-THIRD BIRTHDAY

DR. IRVING LANGMUIR AND DR. A. W. HULL WITH THE THYRATRON POWER TUBE

THE THYRATRON TUBE AND ITS POSSIBILITIES

FROM a series of original investigations of electron discharges in gases which Dr. Irving Langmuir carried out in 1914 in the research laboratory of the General Electric Company has come the thyratron tube, one of the most recent additions to the tube family. It has inherent advantages as a means of controlling electric power, and has begun to be used most effectively in this manner in such unique applications as the system of operating the stage lighting of the Chicago Civic Opera House from in front of the footlights, and the spectacular method of decorating with light the walls and ceilings of rooms, known as colorama.

But it is believed that the possibilities of the thyratron tube are not confined to the function of control. The men who have been responsible for its creation and development believe it may also become the means at some future time of accomplishing power transmission under more advantageous electrical conditions than those at present prevailing. This idea is based on the expectation that the thyratron tube may make it possible to transmit electrical energy over relatively long distances by means of direct current instead of alternating current.

Seeking to develop this proposition, an experimental miniature transmission line has been set up in the General Electric Research Laboratory and equipped with thyratron tubes. The artificial transmission line itself was represented by a copper bar about seven or eight feet in length. Electrical conditions were imposed in the matter of ohmic resistance which made this line equivalent to 400 miles of transmission conductor in a commercial system. As the longest commercial system now in existence is 250 miles in length, this experimental line, in its electrical characteristics, was more than 50 per cent. beyond present practice.

At the sending end of the line was installed a bank of thyratron tubes functioning as rectifiers, to convert alternating current into direct current for transmission purposes. At the receiving end of the line were installed other thyratron tubes which functioned in pairs as inverters. They inverted, or changed back, the direct current into alternating current. The source of current-supply for the experimental system was a bank of transformers which furnished alternating current at 15,000 volts.

When this interesting experiment was tried it was found that transmission of the power was accomplished without difficulty, and that the thyratrons, operating at one end as rectifiers and at the other end as inverters, handled successfully the current at 15,000 volts. At the receiving end the tubes delivered the energy to transformers, which reduced the pressure to the voltage of the working circuits in the laboratory shop, and through these circuits it was put to work in motors, just as is done in every-day practice everywhere.

As a further demonstration, the experiment was later repeated with the addition of a double-conversion process at the receiving end of the experimental line. After having been inverted and sent through "step-down" transformers, the current was passed through a motor-generator set and reconverted again into direct current at working voltages. Thence it was supplied to shop circuits which required direct current for regular work in direct-current motors.

The experiment was regarded as significant of what may be in store at some future period in electrical engineering developments. It is quite possible from

the present trend as revealed by this experiment that within the next decade —precisely how soon laboratory men do not care to speculate—direct-current transmission on a scale comparable with or at least approaching the present practice with alternating current will go into commercial usage.

Not since the earliest days of commercial application of electricity has direct-current transmission been considered practicable. In the electrical beginning of things, when arc lights first came into use, followed a few years later by Edison's incandescent lamp, almost all transmission in commercial systems was by direct current. That was fifty years ago, before the era of wide-spread electrical networks which serve an overwhelming majority of the nation's population. The arc-lamp systems operated on the series circuit and started in 1879 and 1880 with pressures of 2,000 volts, although in more recent times they have gone as high as 8,000 volts. The incandescent system utilized the multiple circuit, and transmission was at the low pressures of 110 or 220 volts. These represent two methods of transmitting economically by direct current, but their disadvantages would be so pronounced if employed under present-day conditions that the development of the transformer and the alternating-current systems that came in shortly before 1890 was little less than the salvation of electrical practice at that period. If transmission by direct current at high voltages can be accomplished, with the aid of the thyratron tube, the benefits both electrically and economically will be decidedly noteworthy.

The thyratron tube has been fifteen years in reaching its present state of development as a perfected and effective control device, with latent possibilities in transmission mentioned above. After Dr. Langmuir had conceived the idea of making use of the characteristics displayed by electron discharges in gases for controlling an electric arc by means of a grid, Toulon, in France, experimented in 1922 with Dr. Langmuir's process and devised an improvement on his method. Later, Dr. Langmuir and his assistants made other improvements. About 1926 Dr. Langmuir envisioned the broad practical possibilities of the principle, and thereafter Dr. A. W. Hull, in the same laboratory, developed the tube to its present status, making its commercial use in controlling power supply a reality. The tube, of the three-electrode type, differs from the familiar pliotron tube in being an arc rectifier in which a power arc is controlled electrostatically by the grid. In its control function it will economically handle relatively large amounts of electric power.

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OUR RAINFALL: HOW IS IT FORMED AND WHAT BECOMES OF IT?

By Dr. GEORGE FRANCIS McEWEN
THE SCRIPPS INSTITUTION OF OCEANOGRAPHY, LA JOLLA, CALIFORNIA

INTRODUCTION

ATMOSPHERIC moisture is carried from the ocean over the land, precipitated in the form of rain or snow, returned as run-off to the ocean and evaporated into the air, thus completing the "water-cycle."

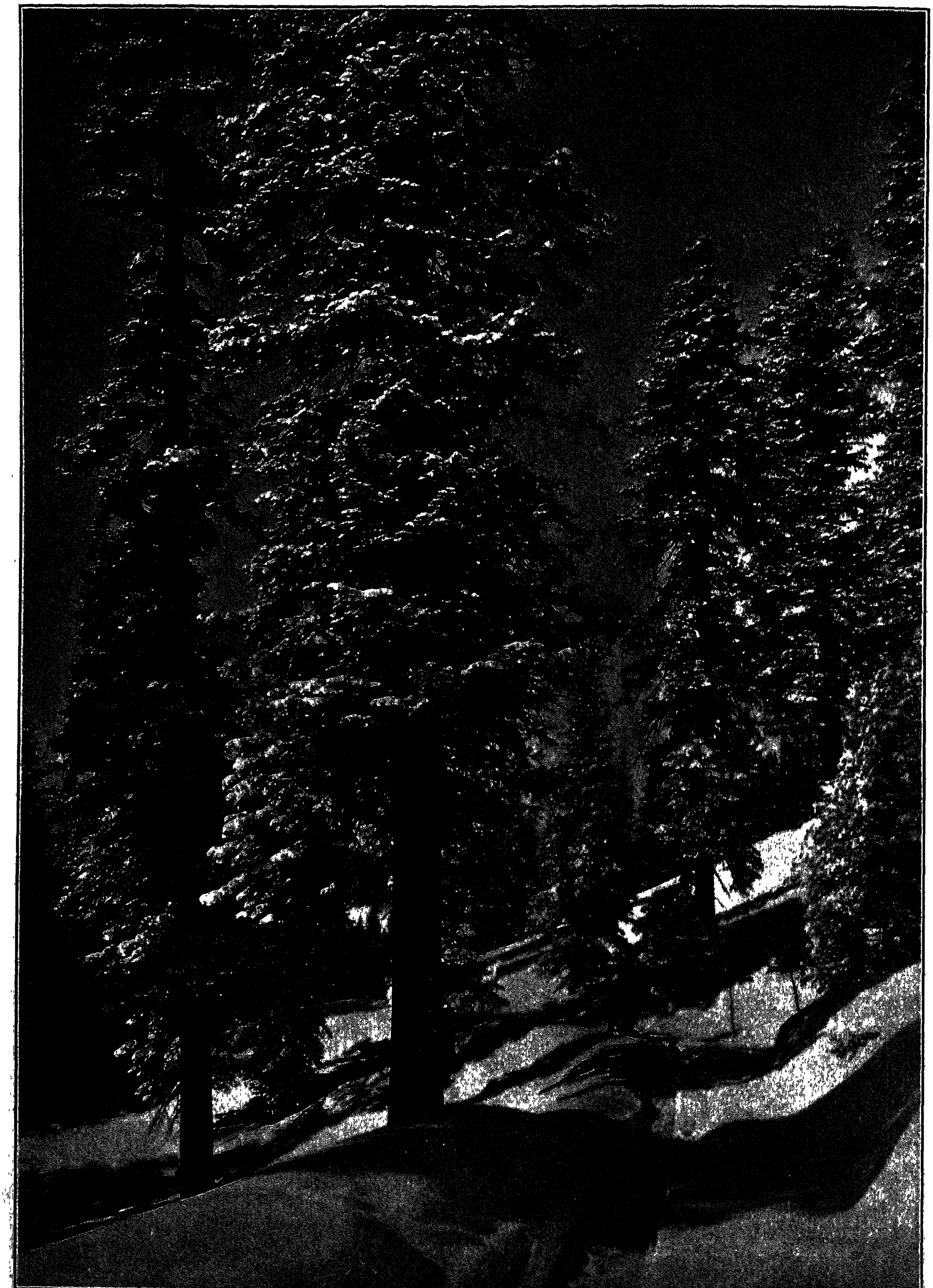
The distribution of water in the atmosphere, the ocean and the land is a momentary aspect of cyclical change. Before considering details of the processes involved in this water cycle some average figures will be presented to indicate the occurrence and distribution of water in the sea, the atmosphere, over the earth's surface and within the geological strata. Some idea of the amount of water in the ocean is revealed by the fact that the salt, if separated from the water, would form a layer nearly fifty yards deep over the whole surface of the earth. The volume of water in the sea is eleven times that of all land above sea-level and is approximately three hundred and twenty-seven million cubic miles, or one eight hundredth that of the earth. While water occurs mainly in the ocean it permeates the atmosphere in the form of vapor, clouds and fog. In addition to its visible occurrence in lakes and reservoirs, large amounts are distributed throughout the soil even down to a depth of thousands of feet in some regions. Using the volume of water in the ocean as a convenient unit a general idea of the average amount of water distributed in these various ways is presented by the following table:

Volume of water in the ocean	1.0
Volume of water in the soil (ground water)	0.005
Volume of water in all inland seas and lakes	0.00009
Volume of water in the atmosphere	0.000009

But the condition is not static. From exposed water and land surfaces there is continual evaporation into the air, where water exists in the form of vapor and is carried in accordance with the atmospheric circulation to be condensed into fogs or clouds, from which a part is precipitated as rain or snow. After precipitation a large proportion returns as run-off to the original source, the ocean, thus completing the water cycle of transformation and transportation.

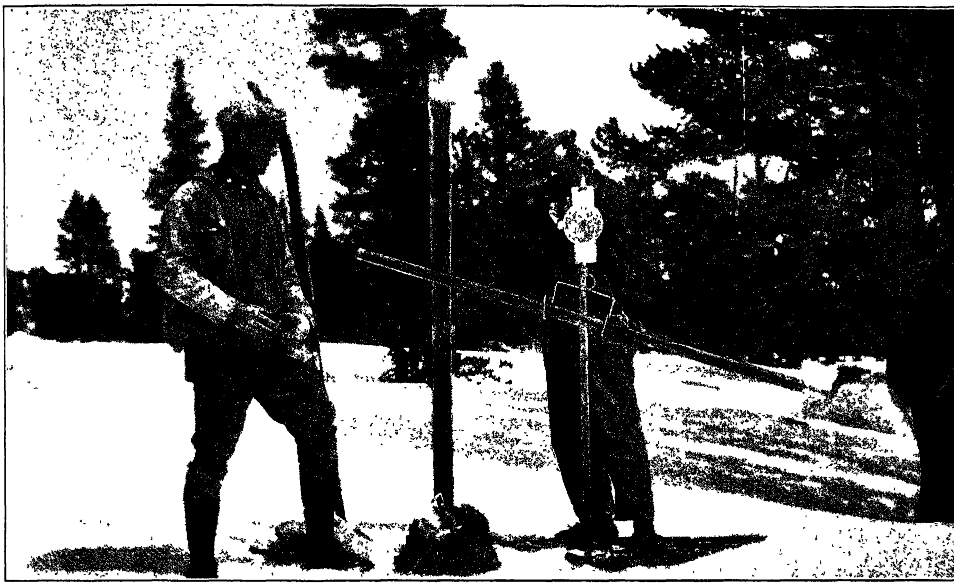
TRANSPORTATION OF WATER VAPOR FROM OCEAN TO LAND

In considering certain details of the different processes that constitute the water cycle let us deal first with the atmosphere and limit our study mainly to the region about the Pacific Ocean. Averages of many thousand observations of wind and barometric pressure indi-



WINTER SCENE IN THE HIGH SIERRAS

MUCH OF THE WATER FOR POWER, IRRIGATION AND DOMESTIC USE COMES IN THE FORM OF SNOW WHICH ACCUMULATES AT HIGH ELEVATIONS.



DETERMINING THE PROBABLE WATER EQUIVALENT OF SNOW

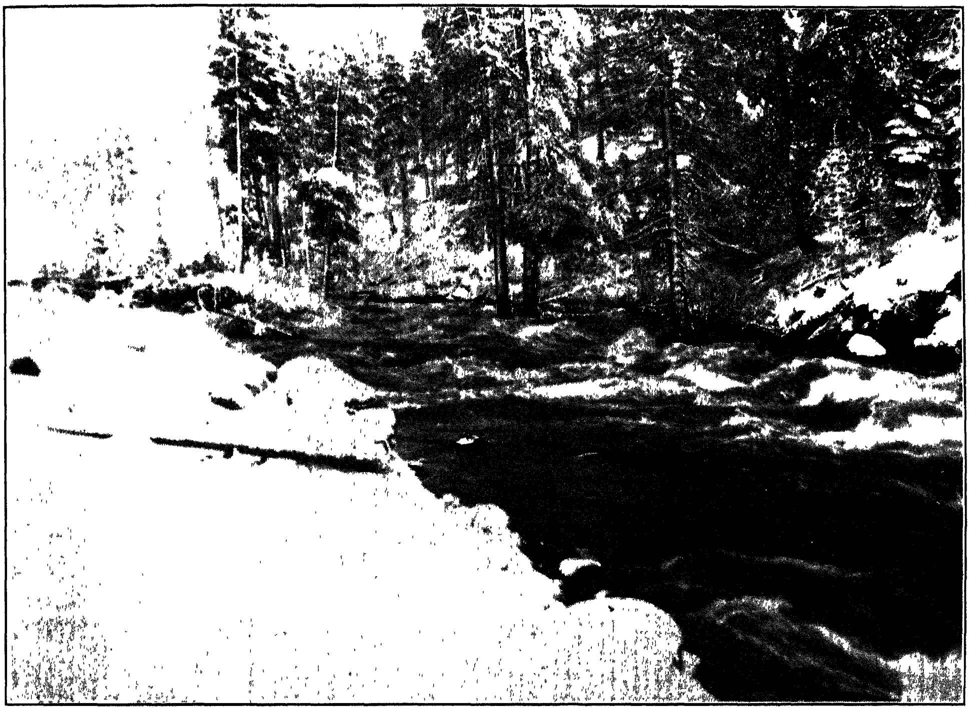
SNOW SURVEYS ARE CONDUCTED EVERY YEAR IN ORDER TO ESTIMATE THE PROBABLE VOLUME OF WATER TO BE EXPECTED WHEN THE SNOW MELTS. THIS SCENE TAKEN AT COTTONWOOD LAKE IN THE HIGH SIERRAS SHOWS THE INSTRUMENTS USED.

cate a high pressure area about a thousand miles west of San Francisco and a low pressure area over the Aleutian region. Winds blow out spirally from the high in a clockwise direction and blow in spirally toward the low in a counter-clockwise direction. From late winter to summer the high moves northward and farther from the coast. It also increases in intensity and area and the prevailing winds become steadier and stronger. The Aleutian low is especially well developed in winter and disappears in summer. South of the equator the winds are clockwise about a low and counter-clockwise about a high. A chart of average winds indicates a line of "convergence" (a line toward which air flows from both sides, usually accompanied by a flow parallel to the line) between the high and low. It is directed toward Vancouver in winter and toward central Alaska in summer. An equatorial line of convergence in the doldrum region is equally prominent, and lies between the two oppositely circulating whirls about the highs of the North and South Pacific. The whole system is subject to a seasonal shift of several hundred miles to the north in our northern summer and to the south in winter. Along both the North and South Pacific coasts of America is a large cold water area between the high and the coast which extends seaward and toward the equator. These areas are especially cold and extensive when the highs and their accompanying winds reach their greatest development. A reduction of as much as 15° F. below the normal temperature for the latitude is occasionally found.

Certain outstanding characteristics of the precipitation of the eastern North Pacific coastal region will now be considered in relation to these atmospheric and oceanic conditions. As a general rule on-shore winds are accompanied by precipitation, while off-shore winds are dry. Polar winds are dry, and winds blowing from lower latitudes into higher

HUNTINGTON LAKE

THIS IS AN IMPORTANT STORAGE RESERVOIR IN THE BIG CREEK SYSTEM OF THE SOUTHERN CALIFORNIA EDISON COMPANY. IT IS LOCATED ABOUT 200 MILES NORTH OF LOS ANGELES AT AN ALTITUDE OF 7,000 FEET IN THE SIERRA NEVADA MOUNTAINS.



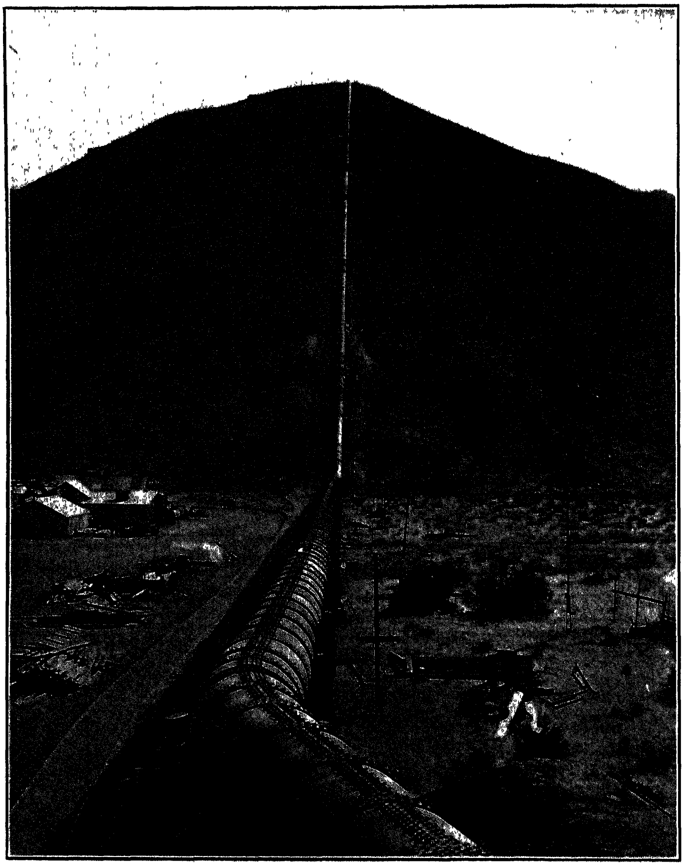
MOUNTAIN STREAM

FED BY MELTING SNOW AND FLOWING INTO HUNTINGTON LAKE

bring much moisture. Lines of convergence have abundant rainfall.

The Pacific Coast State of Colombia in South America has rain at all seasons and is in the doldrum line of convergence. Farther northwards, along the coast from Panama to Guatemala, about 90 per cent. of the precipitation falls during the six-month period from May to October. The northern Mexican frontier located in the off-shore tradewind region is practically arid throughout the year, and north of this region extending as far as Vancouver Island the winter is the rainy season, corresponding to the changes in the high and low. The coasts of British Columbia and Southern Alaska have much rain throughout the year but most of it falls in winter when the frequency of cyclonic storms is greatest.

In addition to these regular seasonal variations there are differences from year to year. Occasionally very great departures occur and can be explained by corresponding changes in the ocean. A striking example of direct ocean influence upon coastal weather is afforded by the westward deflection of the Humboldt current in 1925, which permitted the warm equatorial waters to penetrate southwards along the coast of South America. This unusual development of the warm counter current, El Niño, resulted in abnormally heavy rains along the arid coasts of Ecuador, Peru and Chile. At the same time there was a corresponding deviation of the cold Benguela current, thus permitting the warm waters of the Guinea current to penetrate southward along the west coast of Africa and cause torrential rains along that arid coast. There is some evidence of a recurrence of a similar phenomenon about every thirty-five years.



SYPHON IN THE LOS ANGELES MUNICIPAL AQUEDUCT
THIS SYPHON IS A PART OF THE AQUEDUCT THAT SUPPLIES THE LOS ANGELES DISTRICT WITH WATER FROM OWENS LAKE 240 MILES DISTANT. THE CARRYING CAPACITY IS ABOUT 500,000,000 GALLONS PER DAY.

CONDITIONS ESSENTIAL TO PRECIPITATION

On the average there are about five parts of water vapor per thousand parts of air by weight, and the higher the temperature the greater is the possible amount of atmospheric water vapor. This invisible vapor when cooled sufficiently condenses, forming fogs or clouds. Minute particles, ions, dust, etc., which are widely distributed throughout the atmosphere, act as nuclei which greatly facilitate this condensation. The densest clouds contain about five grams of water per cubic meter of air. An average amount would be near one gram of water per cubic meter of air or about one part in a thousand by weight. Further cooling is necessary to produce precipitation. These drops of water may be as much as two or three millimeters in diameter. Accordingly conditions essential to precipitation are primarily conditions that cool the atmosphere, which is a mixture of air and water vapor. This cooling may be brought about by mixture with relatively cold air, by a flow toward regions of higher latitude where a relatively lower temperature prevails, or by rising and expanding as the pressure decreases. In the atmosphere the latter process of "adiabatic expansion" is by

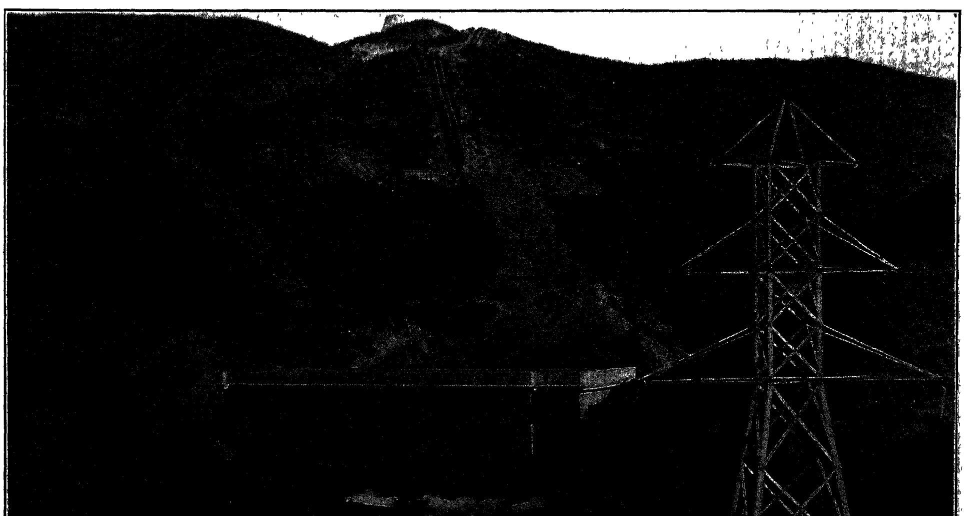
far the most important cooling agency producing clouds and precipitation. Accordingly, it is important to study the conditions that cause a rapid rise of air.

Orographic and Cyclonic Rain and the Polar Front Theory of Storms

A very good example of certain conditions that cause rain is afforded by the warm moist ocean winds blowing to the northwest from the Indian Ocean and turning to the northeast across the Arabian Sea and the Bay of Bengal during the northern summer. These monsoon winds pass over a warm ocean path some four thousand miles in length and are saturated with moisture at a relatively high temperature. Wherever they are directed against steep slopes of coastal mountain chains in India there is heavy precipitation, called orographic because of the topographic factor. The air is deflected upward along these slopes with sufficient velocity to produce a rapid fall in temperature which causes precipitation. Where the winds descend over the warm land surface the air takes up any available moisture and precipitation is impossible.

If the air current is stable (density decreases at a greater than average rate as the height increases), as it is forced up a slope the surrounding air is lighter and thus ascent is resisted. The air will tend to flow out around obstacles rather than to continue upward. This explains why oftentimes the heaviest precipitation does not occur at the top of a mountain, but at some intermediate elevation. Air warmed from below, as often happens in winter when the air is colder than the sea, is unstable, and orographic rainfall is thereby aided. On the other hand, when air is cooled from below, as is often the case in summer over the cold inshore water belt of our California coast, a local fog or slight drizzle results, but orographic rain is hindered.

A different but very important condition producing a rapid updraft of air independently of local topography often develops at a surface of discontinuity, separating warm and cold air at the



A MUNICIPAL HYDROELECTRIC POWER PLANT OF LOS ANGELES

Power is derived from the fall of water which later flows into the city's local storage reservoirs. This plant is located in San Francisquito Canyon.

same level. By means of a very close network of stations in Norway, Professor Bjerknes found that warm winds converging toward colder winds rise above the colder air and their moisture is condensed just as if the warm air were rising up mountain slopes. There is convincing evidence that polar and equatorial air meet at a surface of discontinuity which intersects the surface of the earth and sea in a wavy line extending entirely around the earth at about 50° north latitude but departing hundreds of miles on either side of this average position. Highs and lows result from the separation of loops forming in this line of discontinuity or "polar front."

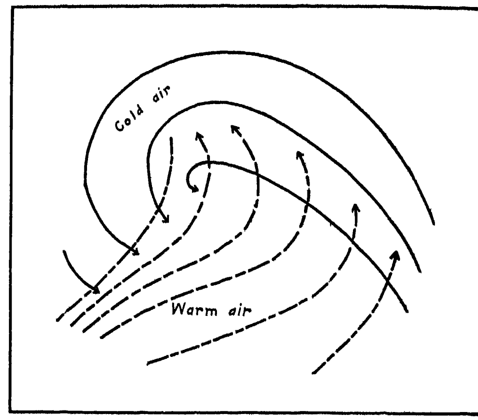


FIG. 1. MECHANICS OF MOVING CYCLONES

THE MOVING CYCLONE CONSISTS ESSENTIALLY OF TWO OPPOSITE CURRENTS—COLD ———, AND WARM – – –.

The weather of the northern hemi-

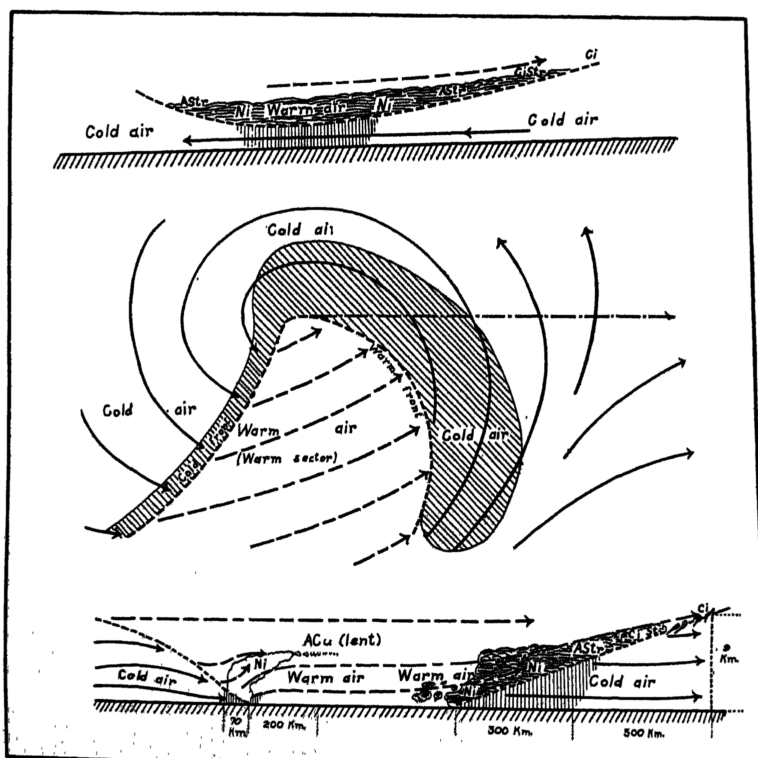


FIG. 2. PRINCIPAL FEATURES OF MOVING CYCLONES

AN AIR MASS OF COLD ORIGIN IS SEPARATED FROM ONE OF WARM ORIGIN BY A DISTINCT BOUNDARY SURFACE – – – – THROUGH THE CENTER INCLINED AT AN ANGLE OF 0.1° TO 1° TOWARDS THE COLD SIDE. CHARACTERISTIC CLOUD TYPES, PRECIPITATION AREAS AND APPROXIMATE DIMENSIONS ARE SHOWN BY THE TWO VERTICAL SECTIONS. THE CYCLONE MOVES IN THE GENERAL DIRECTION OF THE WARM CURRENT AS SHOWN BY THE ARROW IN THE HORIZONTAL SECTION.

sphere is a consequence of advances and retreats of this polar front which marks the frontier between masses of air of different origin. The expulsion of great masses of polar air, forming anticyclones, is an essential element in the general circulation. Warm air flows along the surface of the earth and sea from the subtropic highs toward the polar regions, concentrating in warm tongues and continuing into the polar regions at the upper levels where it cools and later reaches the lower levels. Thus masses of cooled air accumulate behind the polar front and cause it to advance southward. Finally, at places of least resistance great masses of cold air break through and are expelled in the direction of the tropics. This results in a northward retreat of the polar front, after which the process is repeated. Moreover, this intermittent quality of the general atmospheric circulation is especially characteristic of the winter season when marked discontinuities of sea surface temperatures prevail.

A succession of cyclonic storms then develops from alterations of the polar front, and they travel from west to east along tracks which appear as lines of convergence in charts of monthly averages. The structure of one of these cyclones is essentially as follows (see Figs. 1 and 2). There is a warm sector of less than a quarter of the total area and lying to the south; this air flows in a counter-clockwise direction and is deflected upward over the cold air at the right (the observer is assumed to be facing to the north). The cold air also flows in a counter-clockwise direction and forces the warm air upward at the left of the warm sector. Both the boundaries of the warm sector are lines of convergence. According to hydrodynamic theory a line of convergence will move to the right of an observer looking along the line in the direction of flow. Thus there is an ascent of air at both these lines and the cyclone moves from west to east. The spiral motion is due to the combined effect of the low pressure of the central area and the de-

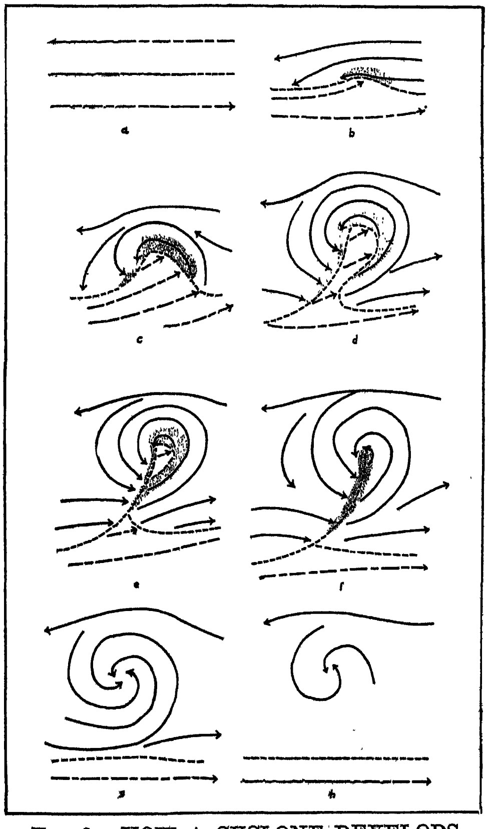
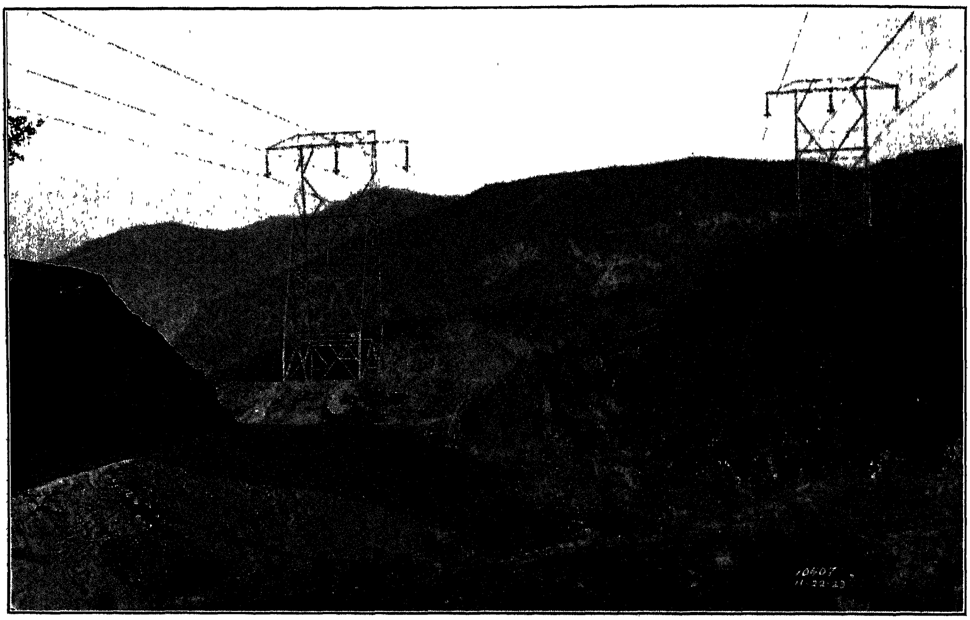


FIG. 3. HOW A CYCLONE DEVELOPS

THIS DIAGRAM SHOWS HOW A CYCLONE DEVELOPS FROM TWO OPPOSITELY DIRECTED (EAST AND WEST FOR EXAMPLE) AIR CURRENTS (A) OF DIFFERENT TEMPERATURES SEPARATED BY A NEARLY STRAIGHT BOUNDARY ---- BY A BULGING OUT TOWARD THE COLD SIDE, (B) AND FORMATION OF A WARM TONGUE (C) WHOSE TIP BECOMES THE CENTER OF THE CYCLONE. THIS WARM TONGUE IS THE WARM SECTOR (D) OF THE NEWLY FORMED CYCLONE WHICH IS PROPAGATED LIKE A WAVE ON THE BOUNDARY SURFACE BETWEEN WARM AND COLD AIR IN THE DIRECTION OF THE WARM CURRENT. THE AMPLITUDE (NORTH AND SOUTH) OF THE WAVE INCREASES, THE WARM TONGUE GROWS NARROWER AND IS FINALLY CUT OFF (D), (E), (F). THE CYCLONE THEN DEGENERATES INTO A VORTEX (G) WITH A COLD CENTER, ITS KINETIC ENERGY CHANGES INTO POTENTIAL AND THE CYCLONE DIES (H).



HIGH VOLTAGE POWER LINES

ELECTRICAL ENERGY GENERATED IN HYDROELECTRIC POWER PLANTS IN THE MOUNTAINS IS TRANSMITTED BY HIGH VOLTAGE LINES TO TRANSFORMER STATIONS.

flecting force due to the earth's rotation. There is at first an interchange of warm and cold air causing a transformation of potential into kinetic energy which changes later into potential energy resulting in the death of the cyclone as indicated in Fig. 3.

Both the irregular and seasonal north and southward displacement of the polar front result in a corresponding migration of the storm tracks, and the position and intensity of the North Pacific high determines how far south these cyclonic storms reach the North American coast. Finally, the sea surface temperatures determined by solar radiation, evaporation and the varying ocean currents are a fundamental control of the highs. Thus we are led to regard the ocean and overlying atmosphere as parts of a complex mechanism driven by the sun's energy and obeying the laws of physics.

THE RETURN FLOW OF WATER FROM LAND TO SEA

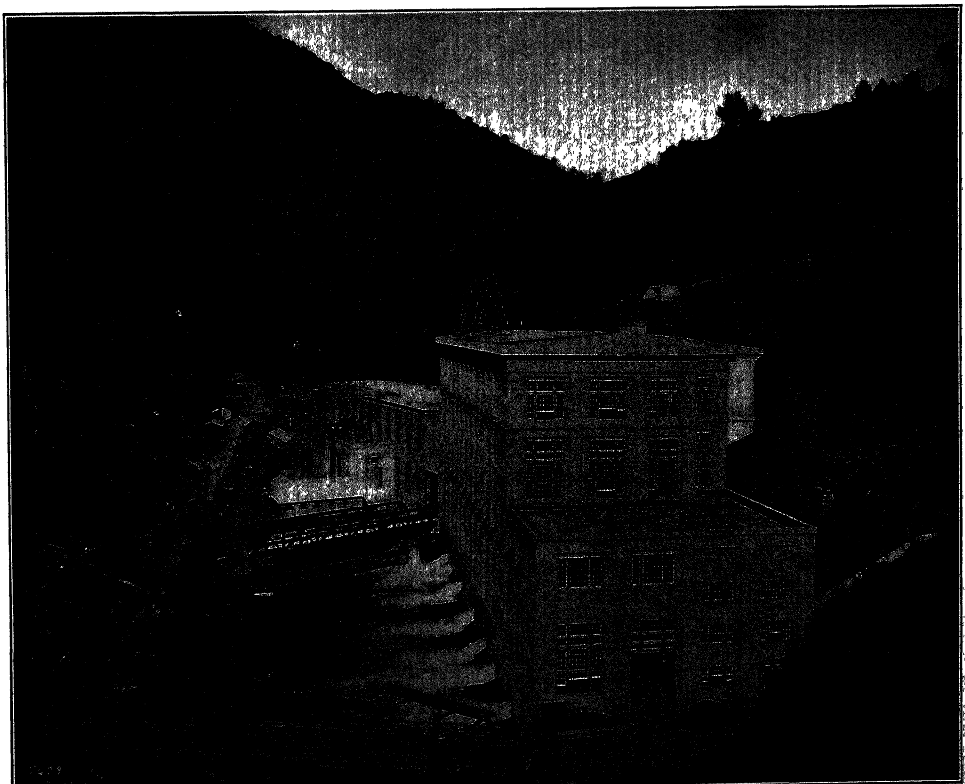
Precipitation varies greatly both with respect to geographic location and time, and may be in the form of rain or snow. A combination of such variability with a corresponding variety of topographic features, types of soil and vegetation results in a great diversity of run-off. A part of the water collects in lakes or artificial reservoirs, some penetrates into the earth's surface forming ground water, some is evaporated and some flows directly into the sea. All these conditions raise important problems in forestry, agriculture and water-supply engineering.

The great economic importance of obtaining an adequate understanding of hydrology, which includes the variations in rainfall intensity and their causes and the relation between rainfall and run-off, is especially recognized by engineers.

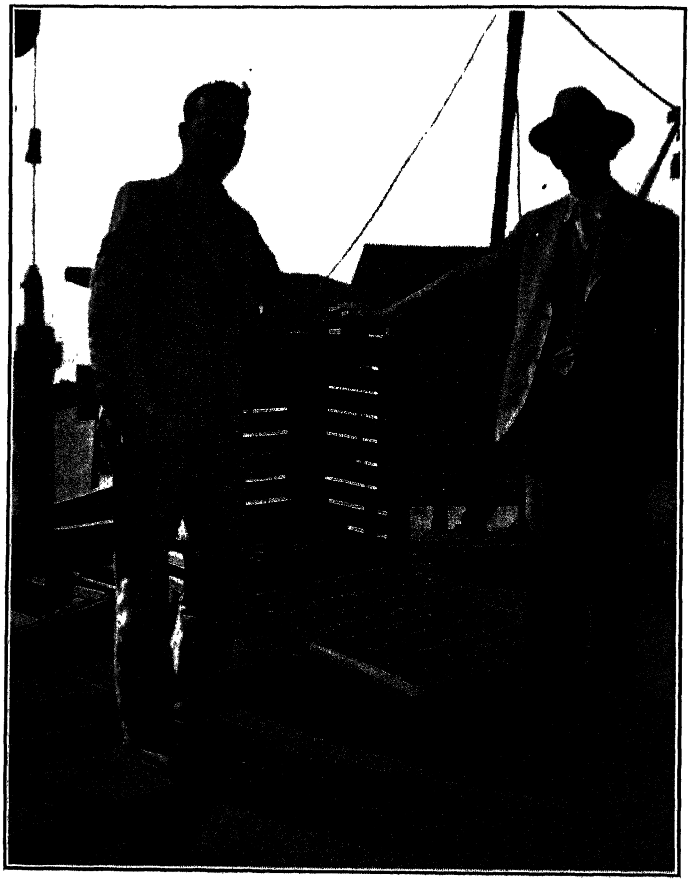
Lack of such basic information has resulted in extensive inundations of highly developed valleys thought to be properly protected by flood control systems. Such disasters have awakened public recognition of the national character of this vital question of flood control. The importance of adequate records of rainfall and run-off and the coordination and interpretation of such data are further illustrated by two cases typical of the West.

In central Arizona where the rainfall and run-off habits are irregular and violent there is along Queen Creek a drainage area of 143 square miles having an annual precipitation of fifteen inches. The run-off is as high as 9,000 second feet at high flood, but the annual average is only fifteen second feet. In contrast to this condition the maximum run-off from an equal area along Cedar Creek in northwestern Washington is 3,600 second feet, the lowest is 294 and the average is 1,089. This average is about 90 per cent. of the total volume from the precipitation of 120 inches per year. This region is characterized by steady, gentle and dependable rainfall, in contrast to the sudden, irregular, brief torrential downpours characteristic of a desert. Accordingly, in arid regions it is necessary to provide reservoirs of relatively great storage capacity to equalize the flow. Furthermore, in order to prevent loss of arable soil and to reduce the silting of reservoirs, the watershed should be provided with a suitable vegetation cover. This has the additional advantage of reducing the variability of the run-off.

The various problems thus suggested



ONE OF THE EDISON COMPANY'S HYDROELECTRIC PLANTS



INSULATED CLOSING WATER-BOTTLE AND THERMOGRAPH FOR RECORDING OCEAN TEMPERATURES

AFTER THE OPEN INSULATED WATER BOTTLE IS SENT DOWN TO THE DESIRED DEPTH, IT IS CLOSED BY RELEASING A WEIGHT WHICH SLIPS ALONG THE CABLE. THE TEMPERATURE IS MEASURED IMMEDIATELY AFTER HAULING THE BOTTLE UP OUT OF THE WATER. THE THERMOGRAPH (IN THE SHELTER) AT THE END OF THE SCRIPPS INSTITUTION'S PIER RECORDS BOTH SURFACE AND BOTTOM TEMPERATURES.

by purely economic considerations can not be solved without a proper basis supplied by investigations of the cause-and-effect relation between rainfall and run-off, and such studies must include the range of conditions influencing rate, sequence and continuity of the various natural processes involved in the rain-producing cycle. Other topics of importance are solar radiation, atmospheric circulation, evaporation, expansion, cooling condensation, deposition, percolation, stream flow and the accretions or losses sustained *en route*.

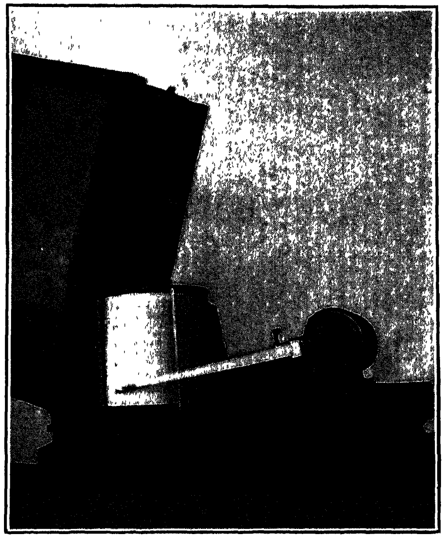
Owing to the interconnection of the oceans and the oceanic circulation the run-off from the land ultimately becomes distributed over the whole surface of the sea. Thus we are led to consider the process of evaporation which completes the water cycle.

Evaporation from Water and Land Surfaces

Although complementary to precipitation and of equal importance there is much less dependable information about the rate of evaporation. This is because

the measurement of precipitation is direct and readily made, while evaporation must be determined indirectly from suitable observations made with the aid of special equipment. For example, direct observations from a pan must be corrected by special methods in order to obtain the evaporation from a neighboring lake or reservoir. Although many investigators have worked on the problem of determining the rate of evaporation from lakes and reservoirs discordant results have been reached, owing to inherent difficulties and to lack of time to carry out a thorough rational investigation of suitable technique. Empirical methods were used and there was neither general agreement as to the relation of pan evaporation to that of a large body of water nor as to the method of estimating evaporation from meteorological data. Even less satisfactory information has been obtained about ocean evaporation, owing not only to certain observational difficulties peculiar to a moving ship, but also to lack of a rational method of interpreting the observations. Available observations indicate a rate of about 2.7 feet per year from the sea. There is also evaporation from the soil which under different conditions varies from about 20 per cent. to 90 per cent. of that from a water surface.

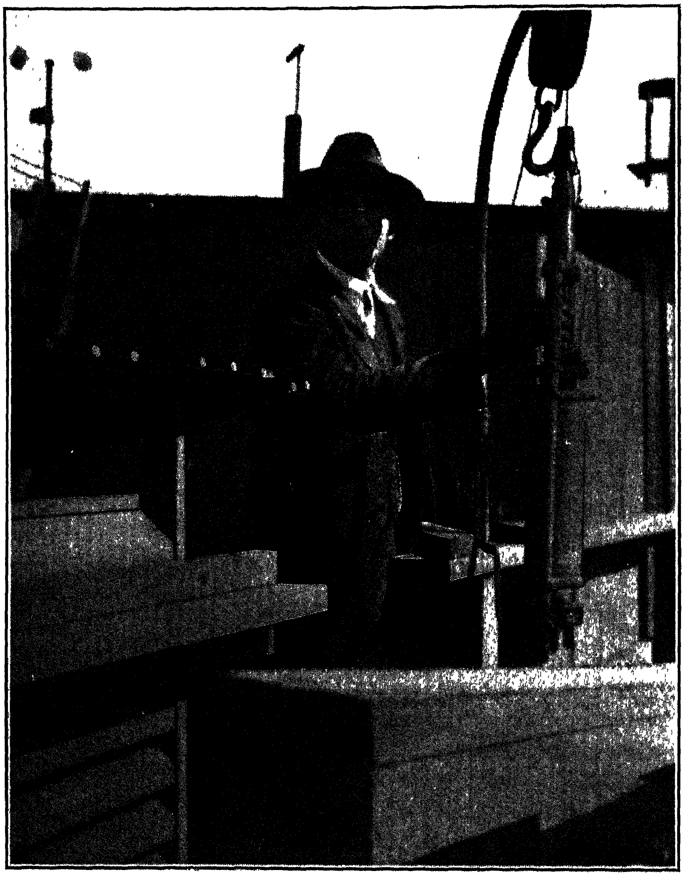
In spite of the need of a clear understanding of the physics of evaporation long recognized by engineers, geologists, meteorologists and oceanographers, no investigation of the subject, leading to satisfactory results, had been carried out before 1920. Mr. Cummings, then assistant in physical oceanography at the Scripps Institution, undertook to make a critical study of the problem of evaporation. This investigation begun at the Scripps Institution led to cooperative work at the California Institute of Technology a few years later by Messrs. Cummings, Bowen, Richardson and Montgomery.



THERMOGRAPH FOR RECORDING OCEAN TEMPERATURES

A STEEL BULB AND CAPILLARY STEEL TUBE LEADING TO THE HOLLOW COILED SPRING ARE FILLED WITH MERCURY WHOSE VOLUME CHANGES WITH THE TEMPERATURE. THE LEVER ARM TERMINATED BY A PEN RECORDS THE TEMPERATURE. THIS INSTRUMENT IS PROVIDED WITH TWO SEPARATE ELEMENTS, ONE FOR THE SURFACE AND ONE FOR THE BOTTOM, BUT RECORDING ON THE SAME PAPER.

Since these investigations of the process of evaporation were based upon the principle of energy exchanges some average estimates are presented first. The rate at which radiant energy from the sun passes through a square centimeter of surface normal to the rays at the outer limits of the atmosphere has been estimated to be two calories per minute, or one fifth horse-power per square foot of normal surface. If this energy were all available at the earth's surface for evaporating water the rate would be one inch per twelve-hour day at the equator and about one half as much at mid latitudes. The actual rate averages nearer 0.1 inch per day. Solar radiation at the earth's surface is much reduced in passing through the atmosphere. Even when the sun is in the



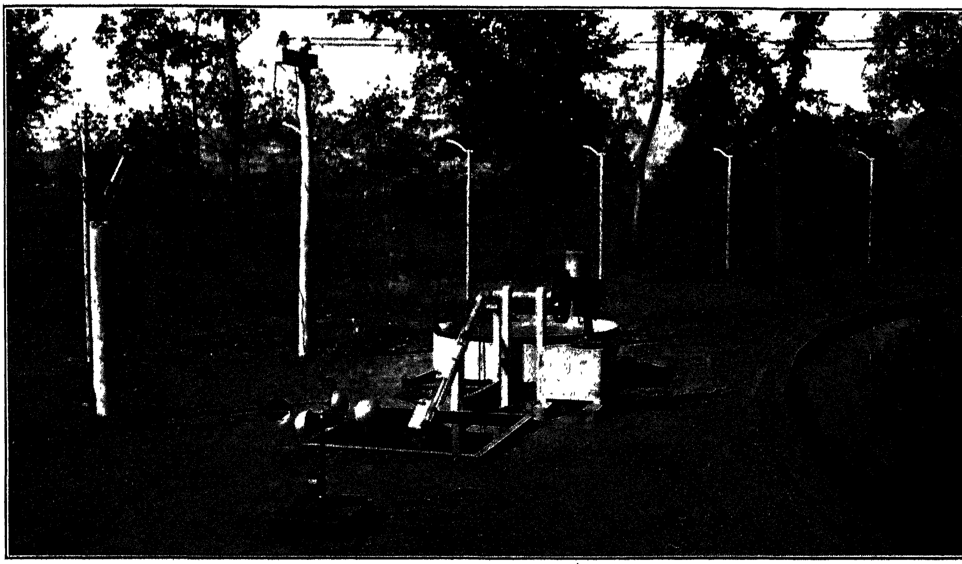
INSULATED WATER-BOTTLE OPEN READY TO LOWER INTO THE WATER

zenith, which position corresponds to the shortest path, and when the air is clear and dry there is a reduction to about 90 per cent. by absorption. Foreign substances, including water vapor in the air, and a departure from the zenith position reduce the amount still more, and dense cloud masses cut off all the radiation.

It is natural to regard evaporation from lakes as a process controlled by atmospheric conditions, such as air temperature, wind and humidity. This view, then shared by Cummings, was not supported by an extensive statistical analysis which he made for the purpose of isolating the effects of various factors influencing evaporation. In particular, a very weak correlation was indicated between evaporation and humidity. He concluded that there must be a fundamental physical reason for this unexpected result.

Accordingly, it was decided to make a new beginning and attack the evaporation problem from the standpoint of the first law of thermodynamics. This investigation led him to the conclusion that any change in wind or humidity is always accompanied by a change in lake temperature which partially neutralizes the direct effect on the evaporation rate to be expected from the original change in atmospheric conditions, if the heat received from the sun remains constant.

Making use of the principle that the



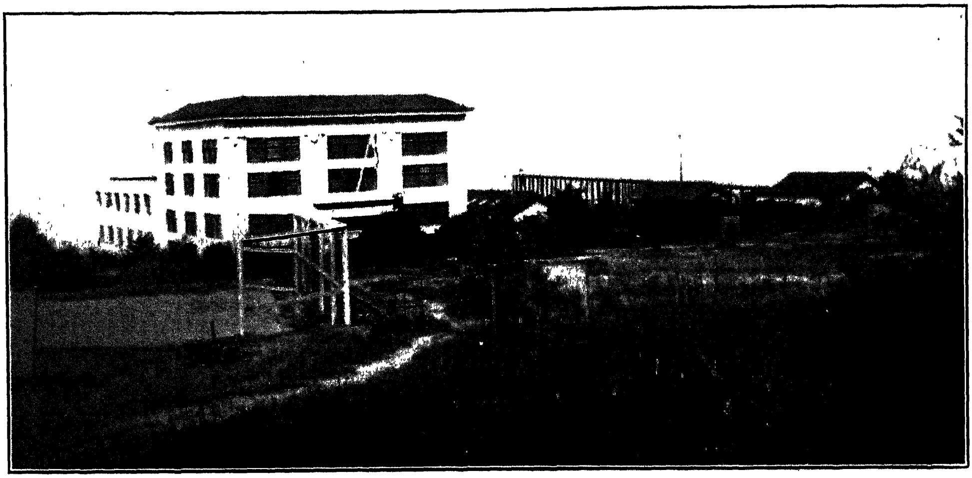
INSTRUMENTAL EQUIPMENT

FOR EVAPORATION MEASUREMENT, INCLUDING WIND VELOCITY AND RELATIVE HUMIDITY.

rate at which energy is removed by evaporation must equal the difference between the rate at which energy is supplied by solar radiation and lost by back radiation corrected for heat storage in the water, Dr. Cummings formulated an approximate equation for computing the evaporation from a lake. Further improvement of the equation resulted from a theoretical investigation by Dr. I. S. Bowen, of the California Institute of Technology, on the ratio of sensible heat carried away by the wind and diffusing into the air to the latent heat carried off by vapor.

Extensive observations conducted by

SCRIPPS INSTITUTION'S PIER VIEWED FROM THE SOUTHEAST



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Dr. Cummings and Mr. Burt Richardson, using containers of various sizes, proved the correctness of the equation, thus modified, and led to a rational and accurate procedure for determining the evaporation from a lake.

During the progress of these investigations I was applying to the general problem of évaporation the principle of equating appropriate rates of energy at each level in the body of water. These investigations led to a mathematical formulation and solution of the problem of the downward diffusion of the surface cooling due to evaporation and back radiation and the heating caused by solar radiation. By means of the theory thus developed, the rate of surface cooling and the rate at which solar radiation penetrates the surface can be estimated from serial temperature and salinity observations. With the help of results outlined above the effect on surface cooling of factors other than evaporation can be eliminated. Thus one of the results of this cooperative undertaking is to provide a possible method of estimating evaporation from the sea.

Conclusion

While a good deal of information has been obtained regarding the water cycle there are many deficiencies as to detail, and there is room for much progress in theoretical studies carried on for the purpose of understanding the physical laws and interpreting the observations. Moreover, we have the fundamental instrumental designs and theoretical technique for making quantitative estimates of the processes that combine to make up the water cycle, but there is need of applying them to an extent commensurate with the importance of this vital world-wide phenomenon.

In the interest of the economy and safety of our public works appropriate observations should be made, having in mind the need of continuity as well as the great cumulative value of the length of records. All pertinent data should be assembled, coordinated, interpreted and made available. It is only by progress in this direction that engineers can solve the various problems that arise in working out the design of projects involving flood control or water supply.

THE ANCIENT LIFE OF YUMA COUNTY, ARIZONA

By Dr. ROY L. MOODIE
SANTA MONICA, CALIFORNIA

A SEARCH for the evidences of disease in ancient times and among ancient creatures often leads me into interesting places. The scenes are visioned not only as they exist to-day but modified by the mental concept of what they were in antiquity, when the creatures we know now only from hard, dried bones were animals of flesh and blood, subject to influences to which living creatures are sensitive.

One fascinating thing about the study of paleopathology is that we never can tell what is going to turn up next—the investigation of which leads us into unsuspected realms of thought. We dream of such things as proving that those huge creatures, the sauropod dinosaurs found in the East African Tendaguru formations, are pituitary giants, though we will probably find the actuality to be something quite different and unsuspected.

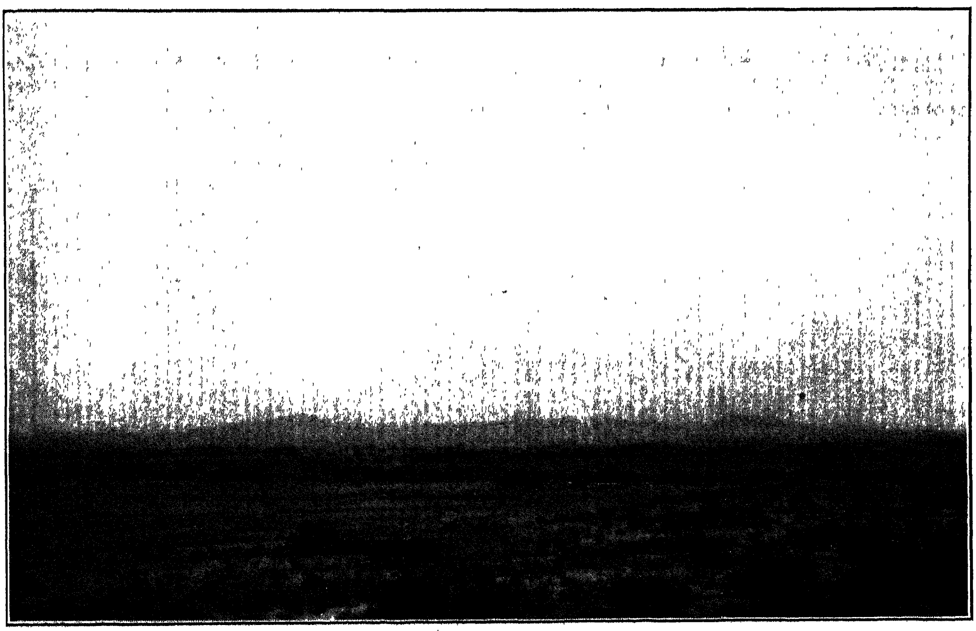


FIG. 1a. THE FLOOR OF THE GILA RIVER

FIFTY-FIVE MILES EAST OF YUMA, IS MANY MILES WIDE, AND IS SUBJECT TO FLOODS, MANY YEARS APART. THE STREAM BED NOW LIES IN THE NORTHERN PART OF THE VALLEY, ITS COURSE BEING MARKED BY TALL COTTONWOOD TREES OF MANY YEARS' GROWTH. THE GILA RIVER VALLEY IS CUT INTO A HEAVY DEPOSIT OF LATE PLEISTOCENE DETRITUS, DERIVED FROM UPLANDS NOW DIFFICULT TO RECOGNIZE. THIS DETRITUS CONTAINS FOSSILS OF MANY KINDS WHICH ARE FAR REMOVED FROM THEIR ORIGINAL PLACE OF DEPOSITION, AND ARE SECONDARY DEPOSITS. ALL THE FOSSILS OBSERVED WERE WORN AS IF ROLLED BY WATER OR ERODED BY WIND. THE BONES ARE INTENSELY PETRIFIED, HEAVY AND WITH PEBBLES MOST THOROUGHLY CEMENTED TO THE SURFACES.

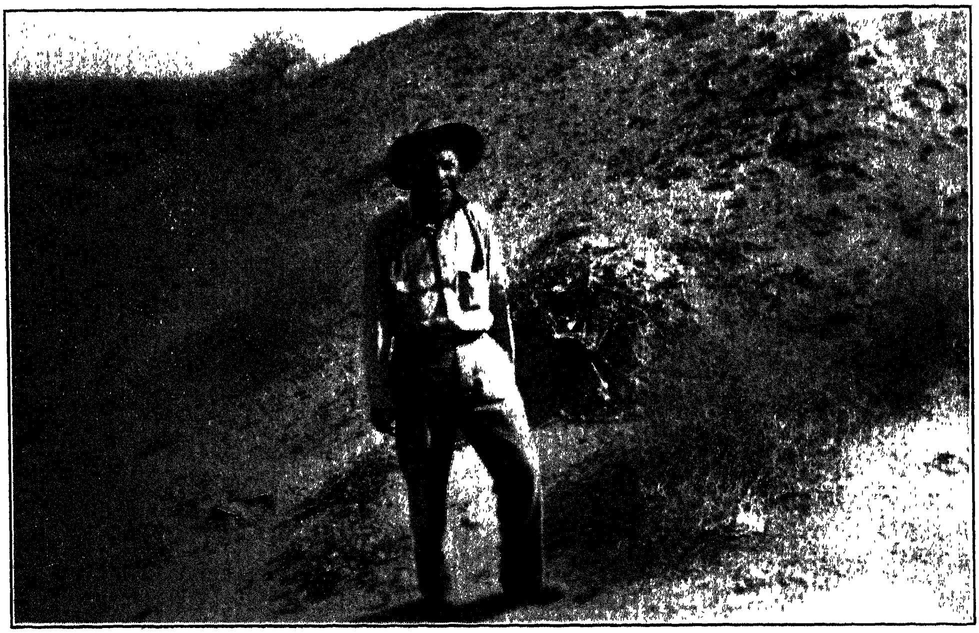
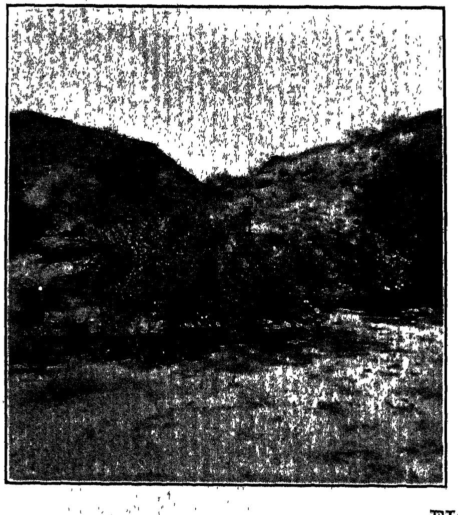


FIG. 1b. ON THE SOUTH RIM OF THE GILA RIVER VALLEY
CHARLIE NORTON STANDS IN THE DEPRESSION FROM WHICH EIGHT YEARS BEFORE HE HAD SECURED THE DISEASED NECK BONES OF A MAMMOTH, SHOWN IN FIG. 3. THE DEPRESSION IS ALSO SHOWN IN FIG. 2, LEFT.



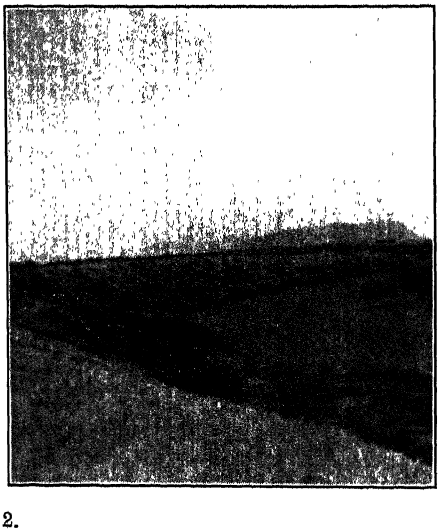


FIG. 2.

A GULLY
HAD YEARS BEFORE CUT A GAP INTO THE SOUTHERN RIM OF THE VALLEY, EXPOSING THE MAMMOTH BONES NEAR THE SPOT WHERE MR. JOHN DOAN STANDS. THE OUTWASH FROM THE GULLY IS IN THE FOREGROUND, UNDISTURBED BY FLOODS.

ANTELOPE HILL
IS A PROMINENT MONADNOCK THREE MILES WEST FROM THE SPOT WHERE THE MAMMOTH BONES WERE FOUND. THE RIM OF THE GILA RIVER VALLEY, IN THE FOREGROUND, IS FAIRLY STEEP AND ABOUT FORTY FEET HIGH.

—*Specimen deposited in the Wellcome Historical Medical Museum, London*

FIG. 3. COOSSIFIED NECK BONES

THE MOST INTENSELY DISEASED CONDITIONS ARE FOUND IN THE COOSSIFIED NECK BONES OF THE MAMMOTH: CERVICALS II TO VII. THIS IS THE SPECIMEN FOUND BY CHARLIE NORTON AT THE LOCALITY SHOWN IN FIGS. 1 AND 2. THE FOSSIL WEIGHS 57 POUNDS, WITH A GREATEST LENGTH OF 480 MM. THE MOST EVIDENT OF THE THREE PATHOLOGICAL CONDITIONS IS TO BE SEEN ON THE VENTRAL SURFACE OF THE BONES (*below*). THIS IS DUE TO THE COMPLETE AND EXAGGERATED OSSIFICATION OF THE VENTRAL LONGITUDINAL LIGAMENT. MEDICAL PEOPLE SPEAK OF THIS CONDITION AS *Spondylitis deformans.* CERVICAL ARTHRITIS, A PHASE OF RHEUMATISM, IS EVIDENT ON THE ARTICULAR SURFACE OF THE AXIS, SEEN TO THE LEFT. SO INTENSE IS THE DISEASED CONDITION THAT THE NECK BONES ARE PULLED OUT OF LINE, RECALLING THE WRYNECK OFTEN SEEN IN HUMANS.

A casual remark from a friend as to his having seen a curiously deformed series of cervical vertebrae of a mammoth led me to secure the loan of the specimen for study. Never had I seen such an object (Fig. 3), in which the pathological bone formed such a dominant amount of the structure. Immediately I saw the series of bones, thoroughly coosified, at once I knew that a scientific treasure had been brought to light. Closer study revealed a combination of difficulties, for the Pleistocene proboscidean not only had a stiff neck, but also a "wryneck," and rheumatism had so changed the articular surfaces of the axis as to lead me to think that all seven of the neck bones were in life firmly attached to the skull by bony lesions, and that probably the rest of the backbone might show evidences of disease. A search for further skeletal parts would be thoroughly worth while.

Inquiry showed that the specimen was the property of Mr. John Doan, of Yuma, Arizona, who was holding it for educational purposes. He readily consented to go with us to the locality which he understood was a gravel pit being excavated for railroad grading. When we reached the place, some fifty miles east of Yuma, this proved not to be the case.

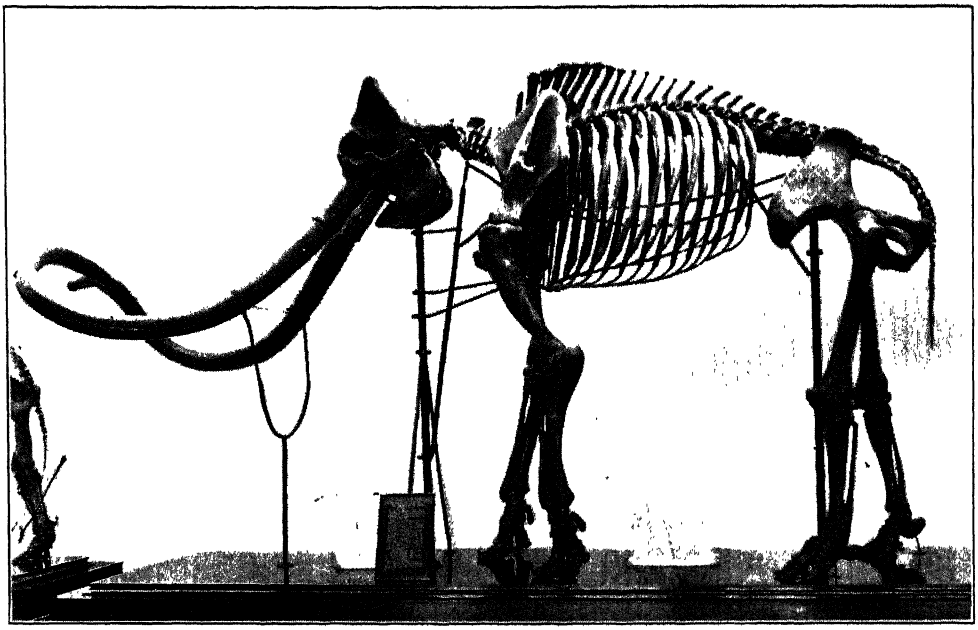


FIG. 4. A SKELETON OF A LARGE MAMMOTH
Archidiskodon imperator (LEIDY) FROM THE RANCHO LA BREA BEDS, AS MOUNTED IN THE LOS ANGELES MUSEUM. THE ANIMAL HAD A HEIGHT OF 13 FEET AT THE SHOULDERS. WHILE THERE IS NO ASSURANCE THAT THE DISEASED BONES SHOWN IN FIG. 3 BELONG TO THIS SPECIES, THEY WILL BE SO REGARDED UNTIL FURTHER EVIDENCE IS BROUGHT FORWARD.

In order not to lose too much time in undirected search along the escarpment of the Gila River Valley, we went in search of the discoverer, Charlie Norton, who was foreman of a group of men clearing brush in the valley near Roll. Since it was late in the day we arranged a meeting for early the next morning, and our party made a most delightful desert camp in the brush near Ralph's Mill on the automobile highway.

The next morning we made our way through the trackless brush to the notch (Fig. 2) in the escarpment, where eight years before Charlie Norton (Fig. 1) had discovered the cervical series which he had given to Mr. Doan. A few scraps of bone, evidently mammalian and possibly proboscidean, and a fragment of the plastron of a river tortoise, were discovered in the search made along the escarpment (Figs. 1 and 2). Whatever of the mammoth had been entombed in this secondary deposit had long since been removed.

Later at the roadside station Tacna we found the upper two thirds of a very large mammoth humerus. The owner said he had seen it sticking out of the bank, evidently near the spot where the neck bones had been found. We heard also of the discovery of the greater part of a huge skull, some years before, which had been broken up for souvenirs. I saw also part of a shoulder-blade and part of the pelvis. I surmised that all these parts represented a single individual, and the size of the bones suggested an imperial mammoth, though we are still unable to prove this classification.

All evidence tended to show that the bones had been moved and secondarily entombed, since all the pieces which I saw were broken and rounded as if rolled by water for some distance.

The mammoths were the largest of the proboscideans, and there were several species which existed in North America during the glacial period. Remains of

the imperial mammoth (Fig. 4) have been found in the asphalt pits of the Rancho la Brea at Los Angeles. Pathological conditions are rare among the mammoths, though not uncommon among the smaller mastodons.

The mastodons and mammoths were companions during the Pleistocene, and it is not surprising that in the loose detritus of the upper plateau in the town of Yuma Mr. Doan found fragments of what seems to be a small mastodon (Fig. 6). Although the head of the proboscideans is huge, yet it is very light because of the immense number of airspaces between the brain case and the outer skull table. Mastodons have previously been recorded from Arizona by Hay.[1] None of these shows disease.

The western horse (*Equus occidentalis*) was originally described by Leidy in 1865 from materials derived from Tuolumne County, California, and may be said to have been fairly common throughout the Southwest. Numerous elements of this horse, 15 hands high, from the Rancho la Brea deposits, in the Los Angeles Museum, show occasional evidences of disease. A complete study of these evidences is contemplated. All the material from Yuma County is healthy.

Of the camels and deer which were probably present we found no trace, although such remains were present in the placers.

A side trip to a petrified forest of undetermined age within a few miles of Yuma was full of interest. The logs and sticks were so thoroughly changed as to ring like steel when struck.

[1] O. P. Hay, "The Pleistocene of the Western Region of North America and its Vertebrated Animals," Publication No. 322 B, Carnegie Institution of Washington. This records the following fossil animals from Arizona: Mammoths, pp. 25, 41, 45; mastodons, p. 10; ground sloth, p. 3; western horse, p. 54; peccary, p. 78; camel, p. 80; deer, p. 107; bison, p. 114. Only a small number are known from Yuma County.

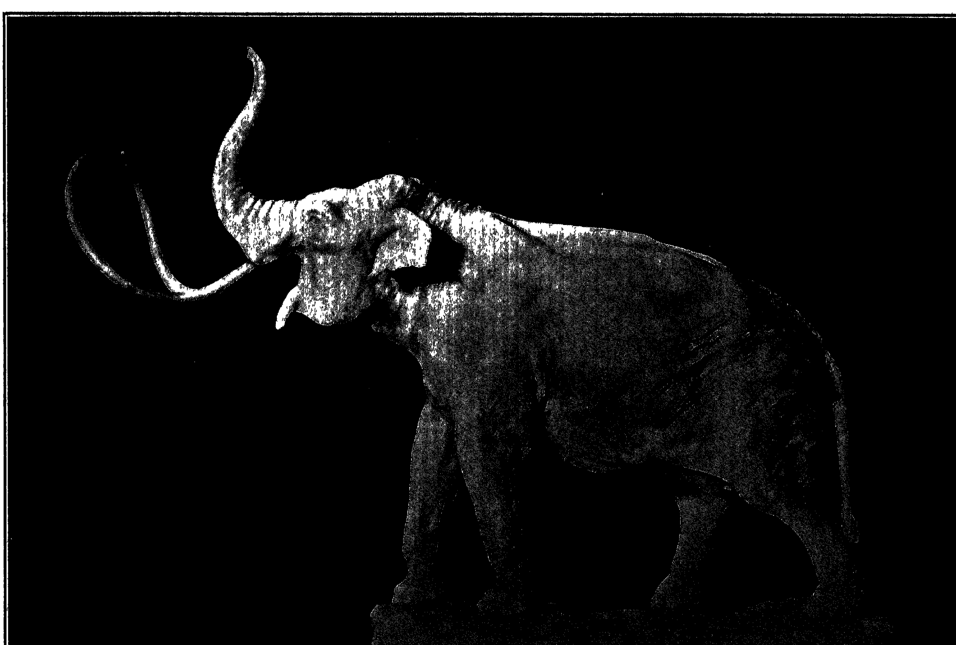
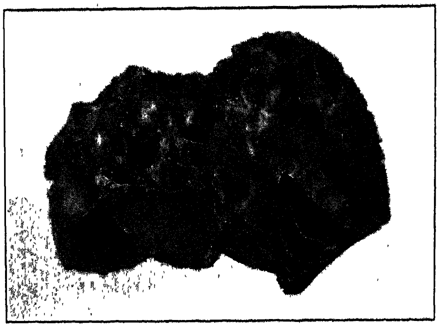


FIG. 5. A RESTORATION OF THE LARGE MAMMOTH
ITS PROBABLE APPEARANCE AS VISIONED BY HENRY FAIRFIELD OSBORN.



—*Specimen collected by John Doan*

FIG. 6. THREE FRAGMENTS OF WHAT SEEM TO BE PORTIONS OF THE OCCIPITAL REGION OF A SMALL MASTODON, FOUND WITHIN THE TOWN OF YUMA, ON A HILL FULLY 200 FEET ABOVE THE COLORADO RIVER, IN LOOSE GRAVEL. THE SMOOTH AREA TO THE LEFT IS A PART OF THE BRAIN CASE. THE SURROUNDING CAVITIES ARE DIPLOIC AIR SPACES, FOR PROTECTION OF THE BRAIN AND TO LIGHTEN THE HUGE CRANIUM.

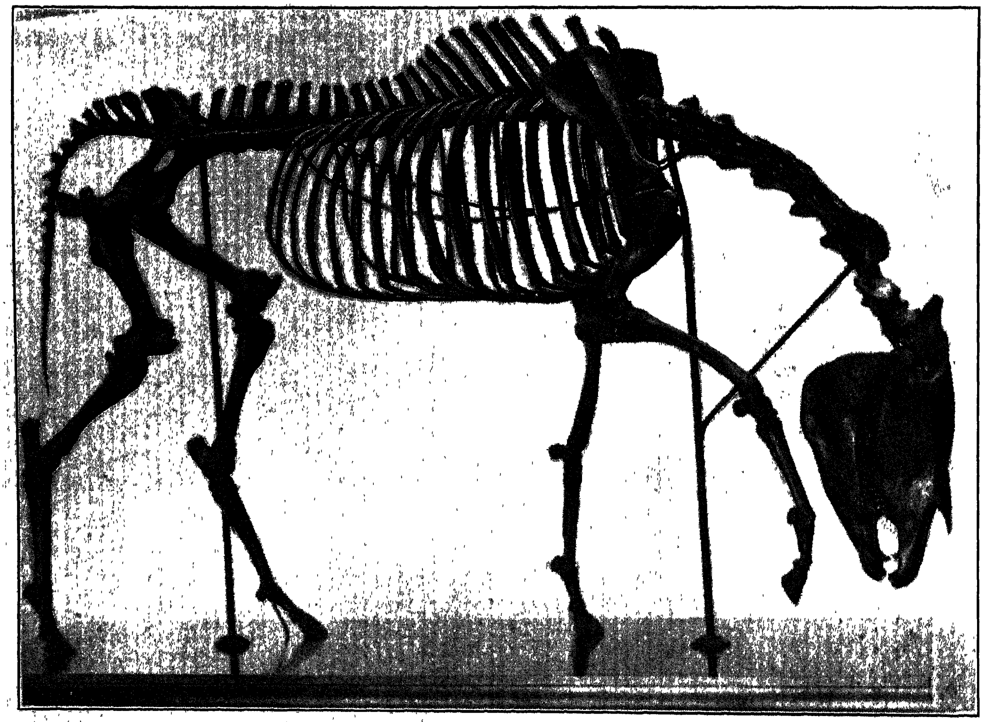
Pictographs (Fig. 9) furnished subjects for discussion, but none of us knew what the figures meant. They seem to have been pecked into the irregular surfaces of an abrupt but rapidly disintegrating basalt cliff. Fragments of rock, bearing pictures or parts of pictures, are falling from the cliff, and in a few years these interesting relics will be gone.

The ancient life of Arizona is not well known, and I have been actuated by a desire to increase the records by giving this brief account of what I have seen.

The following list of publications relates, in part, the scientific sources of information concerning ancient times in Arizona:

Bryan, Kirk
1925. The Papago Country, Arizona. U. S. Geological Survey Water-Supply Paper, No. 499.

On pages 68–69 are given J. W. Gidley's (Smithsonian Institution) report on the finding



—*Courtesy of Los Angeles Museum*

FIG. 7. SKELETONS OF THE *EQUUS OCCIDENTALIS* ARE FOUND IN THE RANCHO LA BREA BEDS, PLEISTOCENE OF LOS ANGELES.

FIG. 8. A SINGLE LOWER MOLAR OF AN EQUINE, FOUND NEAR YUMA, MAY REPRESENT THE WESTERN HORSE, *Equus occidentalis*. GIDLEY HAS IDENTIFIED FOSSILS FROM THE AREA AS OF THIS SPECIES.

of the Pleistocene horse—*Equus occidentalis*), the fossil deer (Odocoileus), in Yuma County.

Farrington, O. C.

1899. A Fossil Egg from South Dakota.

Field Museum Publication, 35. Discusses and figures a fossil egg, unlike the one described by Morgan from Arizona.

Loomis, F. B.

1926. The Evolution of the Horse. Pp. 1–233, 25 plates, 41 figures.

Mallery, Garrick

1893. Picture-Writing of the American Indians.

Tenth Ann'l Report Bureau American Ethnology, 1888–89. Pp. 1–822. 1290 figures. Arizona, pp. 48–51, figures 5–9.

Morgan, Wm. C., and Tallmon, M. C.

A Fossil Egg from Arizona.

Univ. Cal. Publ. Bull. Dept. Geology, Ill.: 403–410, 2 plates.

Osborn, H. F.

1925. The Elephants and Mastodons arrive in America.

Natural History, xxv: Arizona, p. 15.

Ross, C. P.

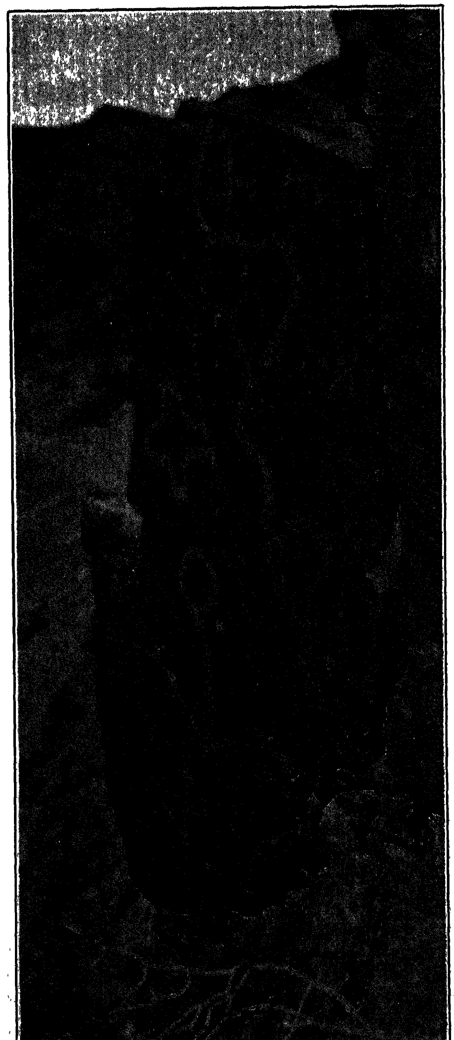
1923. The lower Gila region, Arizona, a geographic, geologic and hydrologic reconnaissance with a guide to desert watering places.

U. S. Geological Survey, Water-Supply Papers 498 i–xiv, 1–137, 233 plates.

Stock, Chester

1930. Rancho la Brea: A Record of Pleistocene Life in California.

Los Angeles Museum, publ. 1, horse, p. 85; fig. 20.



—*Photo by Allison Ketcherside*

FIG. 9. INDIAN PICTOGRAPHS PECKED ON A BASALT CLIFF, NORTH OF THE GILA RIVER BUT NEAR YUMA, ARE STILL CLEAR, AND AS MEANINGLESS NOW AS THEY EVER WERE.

SOME ASPECTS OF THE CHEMISTRY OF GREEN LEAF CELLS[1]

By Dr. HUBERT BRADFORD VICKERY

THE CONNECTICUT AGRICULTURAL EXPERIMENT STATION

In the summer of 1853 two young men, a German of twenty-seven and an American of twenty-three, met in Erdmann's laboratory in Leipzig. The elder was Erdmann's laboratory assistant; the younger was a student who was spending a few months learning the methods of chemical analysis before proceeding to Munich to study under Liebig. Although it is not at all obvious that the meeting of two young men seventy-seven years ago in a German laboratory should have any particular significance, it is one of my objects to show that the ultimate effects of this event are of considerable importance to-day. One of the young men was Heinrich Ritthausen; the other was Samuel William Johnson.

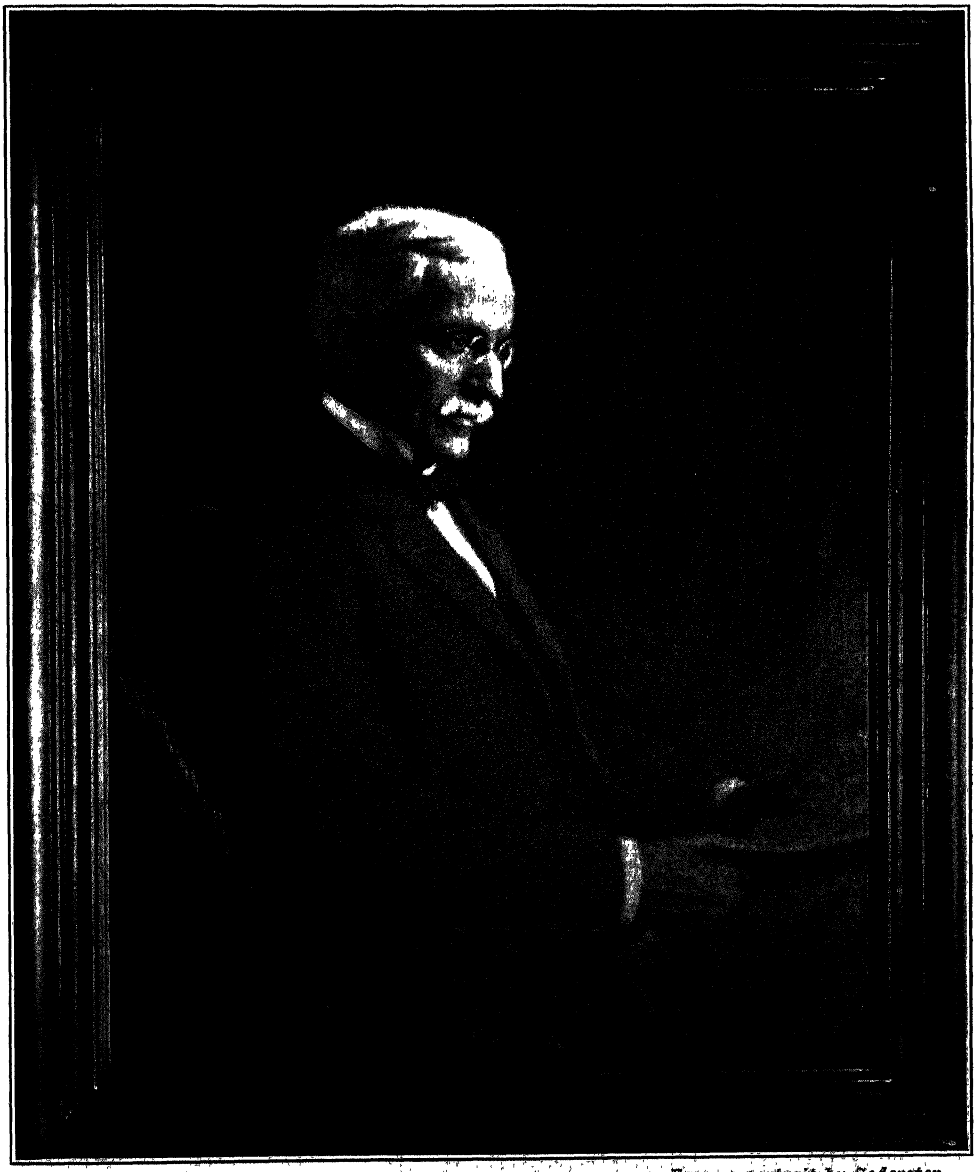
Johnson had long entertained the view that the application of science was essential to the further development of agriculture. His experience in Germany confirmed this idea, and the development of the system of agricultural experiment stations in this country is largely traceable to his efforts. These institutions were founded with the objects of promoting scientific agriculture, of protecting the public from fraud and of fostering fundamental scientific research. The first of them in America was established on a preliminary basis in Connecticut in 1875. A reorganization was made two years later, and Johnson became the director. Although the financial resources of the new institution were almost microscopic at first, all three of the objects of experiment station work were worthily fulfilled. In 1887 an Act of Congress, the Hatch Act, granted federal funds for the express purpose of supporting original scientific investigations in experiment stations. This permitted an enlargement of their activities, and it is significant that one of the first projects undertaken at the Connecticut station was an investigation of vegetable proteins.

In order to account for this let us consider for a moment the career of the other young man of the German laboratory. Ritthausen in 1854 became director of the agricultural experiment station at Möckern, near Leipzig, where work was being conducted of sufficient interest to give rise to several articles from S. W. Johnson's pen in the *Country Gentleman* for 1854. Ritthausen later worked at Waldau and at Poppelsdorf and, finally (1873), was appointed professor of chemistry in the university at Königsberg, where he remained until his retirement in 1899. In 1872 he published a slim volume[2] of some 250 pages in which was described an astonishing amount of original investigation on the proteins of vegetable seeds.

These investigations were little appreciated at the time of their appearance either in Germany or in this country; but among the few men who realized their value was S. W. Johnson, in New Haven. At that time little could be done, but the accession of funds at the Connecticut Experiment Station, because of the passage of the Hatch Act, made it possible to begin investigations along the lines pointed out by Ritthausen. Accordingly, in 1888, Johnson

[1] A lecture delivered at the Carnegie Institution of Washington, D. C., April 30, 1930.

[2] H. Ritthausen, "Die Eiweisskörper der Getreidearten, Hülsenfrüchte und Ölsamen," Bonn, 1872.



—From a portrait by Sodersten

SAMUEL WILLIAM JOHNSON

suggested to his assistant and son-in-law, Thomas B. Osborne, that a study of the nitrogenous substances in plant seeds should be undertaken. The report of the director for 1889 carries the terse statement: "Much time has been given by Dr. Osborne to a study of the nitrogenous matters contained in the kernels of maize and oats." In the following year the first of Osborne's papers on the proteins of vegetable seeds appeared, the beginning of a series of papers on proteins and allied subjects that extended in unbroken sequence for thirty-eight years. The interest that Ritthausen had aroused in Johnson's mind during the student years in Europe thus bore extraordinary fruit.

It is not my present purpose to discuss Osborne's long-continued investigations of the vegetable proteins, important and significant as these may be. I may draw attention, however, to one interesting point. As was the case with Ritthausen in Germany, little attention was at first paid to Osborne's work even by his chemist friends; but the compliment that Johnson had paid to Ritthausen was gracefully returned by Germany when Griessmayer, in 1897, translated all Osborne's papers that had appeared up to that time and published them in book[3] form with the object, as he stated in his preface, of "bringing to light these treasures hidden in the American journals."

This spiritual encouragement was followed in 1904 by encouragement of a more substantial nature when the Carnegie Institution of Washington made its initial grant of funds to support Osborne's investigations. Since that date those who are accustomed to look through the year book of the institution have found each year a few pages in which the progress of his studies of the vegetable proteins has been briefly reported. Taken together these reports describe one of the most extraordinary accomplishments of American biochemistry. It is work upon which the very modern science of nutrition is securely founded.

It is my purpose to discuss in detail one phase only of Osborne's investigations; it is a phase in which he was especially interested during the last years of his life, and it led to the studies upon which the laboratory he organized is now engaged.

The development of the vitamin hypothesis about fifteen years ago, in which Osborne and Mendel, with the support of the Carnegie Institution, were largely instrumental, drew the attention of investigators to the enormous importance of "little things" in nutrition. When animals were restricted to a diet composed of purified fat, carbohydrate, protein and inorganic salts, nutritional failure and serious organic disturbances resulted, unless small addenda consisting of cell material or cell extracts were supplied. Such knowledge as was available showed that the active principles in these addenda were present in only minute amounts. These observations focused attention upon the extremely limited nature of the available information on the chemical composition of cells and emphasized the necessity of thorough investigation of them. A broad field of research was thereby revealed. The accomplishments of the past ten years show that this type of work is extraordinarily fruitful. It is necessary only to refer to Sir F. Gowland Hopkins' discovery of glutathione in yeast and to the results of the intensive investigation of the tuberculosis bacillus now being carried on in this country to illustrate my meaning. Osborne and Mendel's feeding experiments had shown that green leaf cells were valuable sources of those highly potent nutritional principles, the vitamins. This observation was the more interesting since green leaves form almost the entire food of many animal species;

3 V. Griessmayer, "Die Proteide der Getreidearten, Hülsenfrüchte und Ölsamen, sowie einiger Steinfrüchte," Heidelberg, 1897.

THOMAS B. OSBORNE

it would therefore appear that in them nature had provided an adequate diet.

Leaves have long been known to contain proteins. The precipitate that separates when leaf juices are heated was recognized a hundred and forty years ago to be very like the coagulum produced by heating egg white and was designated "albumin," a name that recalls this similarity. The Germans were even more specific with their designation "Eiweiss."

Although many attempts have been made to ascertain how much protein leaves contain, the problem is one that is still unsolved. The leaf proteins are enclosed within cell walls which must be ruptured before all the protein can be extracted. This is extremely difficult to do, thoroughly, on a sufficiently large amount of material. The cell contains enzymes that rapidly convert one constituent into another. The activity of these enzymes can not be suspended during the operations of grinding and extracting the protein; accordingly one can scarcely hope to find unaltered cell protein in such extracts. Furthermore, the cell contains a large number of non-protein constituents, of known and of unknown nature, from which the protein must be separated in order to obtain preparations that even roughly approximate purity. In short, in the leaf one is faced with a condition of physiological activity totally different from that encountered in the seed. The proteins of seeds are reserve stores of food that are not called upon until growth of the embryo takes place. As laid down in the seed they have considerable chemical stability and, consequently, can be extracted and isolated with some ease in relatively pure form. But the leaf protein is one of the reagents in the complex series of chemical events that is recognized as life. What part it plays in metabolism is unknown, but certainly it has something to do with the delicate chemical and physicochemical equilibria within the cell.

These considerations indicate that attempts to isolate the proteins of the green leaf are, from one point of view, the pursuit of a will-o'-the-wisp. It is highly improbable that the substance ultimately secured and, with a feeling of triumph, labeled green leaf protein is identical with the stuff that shared in the reactions of the cell. It is even less certain that the preparations represent homogeneous chemical entities. On the other hand, from such preparations much can be learned of the complex nature of cell reactions and much also of the value of green leaves as animal food.

Consequently, in spite of the many uncertainties involved, Osborne[4] attempted about ten years ago to isolate the proteins of spinach and alfalfa leaves. He recognized the desirability of discovering as much as possible about the composition of some single, but typical, cellular material, in the hope that the information might lead to generalizations upon the subject of cell composition. He realized, however, that worth-while results could be secured only after suitable methods for such investigations had been developed, and, as the work has gone on, it has become increasingly clear that the crux of the whole problem is this question of methods.

Large quantities of leaves were thoroughly disintegrated by grinding repeatedly in a suitable mill. The pulp was then subjected to pressure in a hydraulic press. In this way a clear fluid, the undiluted juice of the cell, could be obtained. When this was treated with alcohol, a precipitate separated that was mainly a mixture of proteins and inorganic salts. This precipitate was treated in various ways with the object of re-

[4] T. B. Osborne and A. J. Wakeman, *J. Biol. Chem.*, 42: 1, 1920; T. B. Osborne, A. J. Wakeman and C. S. Leavenworth, *J. Biol. Chem.*, 49: 63, 1921.

moving the non-protein impurities. The most effective method was to warm the material for a short time at 80° in the presence of a weak solution of alkali in diluted alcohol. Under these conditions the substance largely dissolved, and the clear filtrate, when neutralized, yielded a flocculent precipitate that contained 16.36 per cent. of nitrogen and gave all the reactions of proteins. The treatment at 80° with dilute alkali profoundly altered the properties of the crude protein. Evidence was obtained that a non-protein group was thereby split off, and it appeared probable, therefore, that a considerable part of the crude protein material was of the so-called conjugated type. The conjugate group was not identified but was a colored substance of complex nature.

The leaf residue from which the clear juice had been expressed retained about one half the nitrogen of the original leaf. Surprisingly little of this nitrogen could be extracted by dilute aqueous alkali, although this reagent is usually a very effective solvent for proteins. The residue was therefore treated with dilute alcoholic alkali for a few minutes at boiling temperature. This reagent extracted nearly all the residual nitrogen and preparations of protein could readily be secured from the solutions.

The table shows the quantitative results thus secured. It is evident, from

	Solids gm	Solids Per cent.	Nitrogen gm	Nitrogen Per cent.
In alfalfa taken	4,442	100	211.6	100
Press juice	1,898	42.7	92.6	43.8
Alcohol extract	283	6.4	4.3	2.0
0.3 per cent. aqueous NaOH	230	5.2	14.8	7.0
0.3 per cent. alcoholic NaOH	761	17.8	83.2	39.3
Extracted residue	1,292	29.1	11.1	5.3
Total	4,464	101.2	206.0	97.4

the small proportion of the total nitrogen in the final residue, that very few of the cells of the leaf escaped rupture during the grinding and pressing operations and the extractions. Examination of the different extracts indicated that only from 66 to 75 per cent. of the leaf nitrogen belonged to proteins, but so rough an estimate as this was not at all satisfactory. Furthermore it was impossible to determine from the data what parts of the cell were represented by the different fractions.

The failure of these methods to give results that could be interpreted in terms of cell physiology induced A. C. Chibnall, who worked with us from 1922 to 1924, to devise a method[5] whereby the soluble contents of the cell vacuole might be removed before the cell walls were ruptured by grinding. It has long been known that a fluid can be readily expressed from leaves after plasmolysis of the cells by freezing or by the vapors of ether or chloroform. Exactly what happens under these conditions is a matter of debate. When a leaf cell is treated with ether while under microscopic observation the cytoplasm that lines the cell wall can be seen to shrink together and the vacuole liquid within the cytoplasm to pass through it. The permeability of the cell is entirely changed, and the forces that retained the structures *in situ* no longer operate. Chibnall found that, if leaves of spinach or alfalfa are immersed in ether, plasmolysis occurs very promptly and the whole fluid contents of the cells can then be readily expressed under the hydraulic press. The nearly dry leaf residue rapidly imbibes water and, by alternately adding water to the loosened presscake and pressing, a thorough washing can be effected. By this method the cell walls are not ruptured and the formed elements within the cell are retained.

The vacuole fluid, when heated to 85°, gave a small coagulum of protein. The

[5] A. C. Chibnall, *J. Biol. Chem.*, 55: 333, 1923.

amount in the case of alfalfa was very small and amounted only to the equivalent of 0.25 per cent. of the leaf solids and 0.56 per cent. of the leaf nitrogen. It was clear that very little if any of the leaf protein occurs dissolved in the vacuole fluid. The bulk of the protein must therefore be present in the jelly-like cytoplasm that had not passed through the cell walls. The presscakes were thoroughly ground with the addition of a liberal amount of water; the coarser particles were strained out on fine silk, and the turbid aqueous suspension was filtered on a thick pad of paper pulp. A clear yellow-brown solution was secured which, when treated with a very small amount of dilute acid, yielded a copious precipitate of protein. The precipitate was removed, dissolved in a little alkali, reprecipitated by neutralization and then extensively washed by alcohol and ether which removed small amounts of impurities. It contained 16.25 per cent. of nitrogen and gave all the reactions of proteins.

This preparation represented a much more clearly defined entity than did the material secured from alfalfa juice by alcohol precipitation. It is that part of the cytoplasmic protein that passed into solution during the grinding operations. There were grounds for supposing, therefore, that it represented a part, at least, of the protein of the cytoplasm in a not extensively altered condition. Time is an important factor in success with this type of work. If the leaf residue is allowed to stand a few hours before working up, the yield is greatly reduced, while if twenty-four hours elapse only negligible amounts of protein can be obtained. The protein actually secured under the best conditions represents little more than a fifth of the probable amount in the tissue. The great reduction in yield brought about by delay in the grinding operations renders it likely that rapid *post-mortem* changes in the solubility of the cytoplasmic protein occur, as a result of which it becomes increasingly difficult to disperse the substance into colloidal solution by grinding with water.

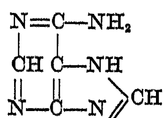
The results of the work on the proteins of green leaves have been, on the whole, decidedly disappointing. The difficulties of preparing representative samples of them are almost insuperable by any method that has yet been devised and, as I suggested a few moments ago, there is little evidence that the material isolated and labeled is indeed the substance that plays so vital a part in the activities of the cell. But there are few problems of leaf cell chemistry more important than the investigation of these substances.

Such evidence as we have been able to secure indicates that physiologically active leaf proteins are distinctly different in their solubility relations from the better known seed proteins. Their amino acid composition, however, so far as it has been ascertained, presents nothing distinctive. All the amino acids that are known to be essential in nutrition are present in liberal amounts, and the high nutritive value of these proteins therefore receives some rational explanation.

I pointed out a little while ago that these investigations had their origin in part from the observation that green leaf material displays a very marked vitamin potency. Numerous experiments with extracts of alfalfa leaves showed that the vitamin B potency appeared in the water-soluble non-protein fraction, that is, in the solution which represents the vacuole content of the cells. This observation furnished a stimulus for the examination of the leaf cell extract and gave rise to the investigations that are now being actively continued.

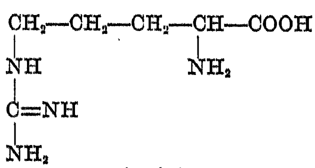
The investigation of green leaf extracts has been a matter of concern in some quarters for many years. The chief figure in the older literature is Schulze, the discoverer of arginin and

phenylalanin. A perusal of his voluminous papers shows that he was chiefly interested in the distribution of single substances in nature rather than in the detailed investigation of a single type of cell. Nevertheless, from Schulze's papers and from those of later investigators, a fairly clear idea may be obtained of the nature of the substances that are likely to be found in a given leaf extract. In general, nitrogenous bases of four distinct types are present, which are roughly classified, for practical purposes, according to the differences in their behavior towards silver salts. The purin bases, such as adenin, form silver compounds that are insoluble in acids;



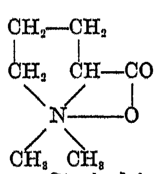
Adenin

the arginin type of base forms silver compounds that are precipitated only



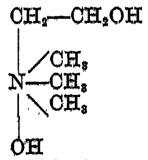
Arginin

when the solution is made alkaline; the quaternary bases, such as stachydrin,

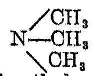


Stachydrin

cholin and the amines, do not form in-

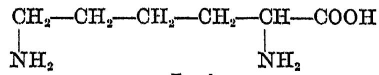


Cholin



Trimethylamin

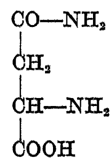
soluble silver compounds. The well-known protein hydrolysis product lysin,



Lysin

which is also found in this class, exemplifies the fourth type of base.

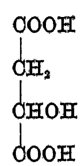
In addition to nitrogenous bases, a complex mixture of amino acids and peptides is found in leaf extracts, together with very considerable amounts of amides of which asparagin, the amide



Asparagin

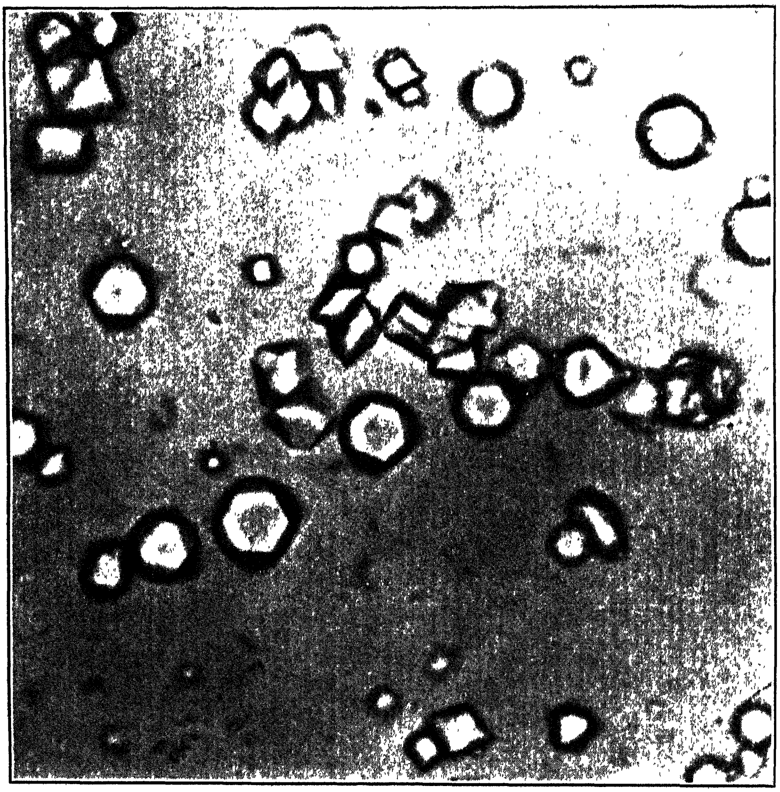
of aspartic acid, is usually the most plentiful.

Although a mixture of these nitrogenous substances only is complex enough to tax the resourcefulness of any analyst, the complexities do not end here. In addition in plant extracts there is invariably a wide assortment of carbohydrates, pectins, gums, resins and allied substances, organic acids of the malic acid



Malic Acid

type, salts of phosphoric acid and nitric acid, of calcium, magnesium, iron, sodium, potassium and other inorganic ions and last, but most prominent and annoying of all, a mixture of pigmented substances, or the precursors of such, of an unknown nature but of astonishingly varied chemical properties.



GLOBULIN FROM TOBACCO SEED
FIRST CRYSTALLIZED IN MARCH, 1930.

The problem we set ourselves was to isolate, in definite crystalline form, as many of these substances as possible, knowing full well that this brief list takes no account of what is unknown about the composition of the extract.

The problem quickly reduced itself to a study of methods of fractionation into main groups, methods for the analysis of these groups into their components and methods for the identification of the components themselves. This meant, in turn, the search for reagents that would precipitate definite groups of substances, so that our analytical operations could be conducted on simplified mixtures.

The essential requirements of a reagent to be employed in this kind of work are that it must precipitate a definite type of compound cleanly and quantitatively, it must precipitate as little of any other type as possible, it must introduce no nitrogen and it must be removable from the solution afterwards in some simple manner. These requirements limit one's choice to salts of metals, such as mercury, silver, copper and lead, with such easily removed acid radicals as the chloride, sulphate or acetate. Phosphotungstic acid and complex iodides are widely employed for certain separations. Nitrates, phosphates and alkali ions such as sodium or potassium must be avoided as much as possible.

It is clear, then, that our choice is severely circumscribed by considerations of a purely practical nature. We have nevertheless been able to select a sequence of reagents to be used as precipitants, and the scheme we finally adopted is relatively simple in outline. It differs fundamentally from any

scheme previously employed for this purpose, but, as our investigations proceed, we are becoming increasingly confident in its power.

The first step is the preparation of an extract of the leaf material that shall contain as much of the simpler substances of the cell sap as possible. The grinding and pressing operations employed by Osborne in his earlier work on leaf proteins yield a fluid that is essentially the undiluted vacuole content together with much protein. This fluid was freed from protein by treatment with an equal volume of alcohol, and the filtrate from this precipitate was employed in all our work on alfalfa.[6] Recently, however, we have prepared extracts by the much simpler method of plunging the fresh leaves into boiling water and then cooking them for a short time. In this way the proteins are coagulated, the enzymes are destroyed immediately and, by pressing the leaves and washing the presscakes thoroughly with hot water, we secure extracts that contain practically the whole of the simpler nitrogenous substances. Doubtless chemical changes of an irreversible nature occur during these operations but, for the present, we regard the losses as being far outweighed by the gains. This applies particularly to the inactivation of the enzymes. We were always apprehensive, when dealing with leaf extracts made by the older method, that extensive changes might have occurred before the enzymes in the extracts were finally destroyed by heating.

The extract is concentrated and treated with one to two volumes of alcohol to remove residual protein and much of the inorganic salt. The filtrate is then freed from alcohol.

Barium hydroxide must be used repeatedly during the analytical operations on the cell extract, and this base forms insoluble compounds with many of the organic acids and other substances that are present. In order to remove these we therefore next add an excess of this reagent and filter off the precipitate. We have found barium hydroxide superior to basic lead acetate, the preliminary reagent employed by Schulze and almost all others who have undertaken this type of investigation, since little nitrogen is precipitated by it and the precipitate forms admirable material for the study of the organic acids of the leaf.

The next step is the precipitation of the organic bases and amino acids. Neuberg and Kerb[7] showed many years ago that α amino acids and many bases could be quantitatively precipitated by mercuric acetate from a solution that was maintained faintly alkaline with sodium carbonate. So far as we are aware no other reagent does this so effectively. Although the procedure involves the use of sodium carbonate and therefore violates one of the primary principles we have laid down for the selection of reagents, we here have a situation where the gains outweigh the losses.

The reaction that occurs is not without interest. The compound that is formed, when mercuric acetate and sodium carbonate are added to a solution of an amino acid, contains carbon dioxide, and is analogous to the carbamino acids employed long ago by Siegfried in his investigations of amino acids, and more recently by Buston and Schryver.[8] It is apparently a basic mercuric salt of the carbamino acid derived from the amino acid.

When mercuric acetate and sodium carbonate are added alternately to the leaf extract a copious precipitate is produced that becomes yellow in color when excess of both reagents is present. An equal volume of alcohol is finally added to promote the flocculation of the precipitate, and this is then removed, washed and suspended in water, acidi-

[6] H. B. Vickery, *J. Biol. Chem.*, 65: 81, 1925; 65: 657, 1925.

[7] C. Neuberg and J. Kerb, *Biochem. Z.*, 40: 498, 1912.

[8] H. W. Buston and S. B. Schryver, *Biochem. J.*, 15: 636, 1921.

fied with sulphuric acid and decomposed with hydrogen sulphide.

The precipitate contains all but insignificant amounts of the amino nitrogen of the extract and all the organic bases except the quaternary bases and amines. The filtrate is acidified with hydrochloric acid and freed from mercury. It contains the quaternary bases and amines, the sugars, insignificant residues of amino acid material due to the solubility of the mercury precipitate and a large amount of sodium chloride.

By this fractionation we greatly simplify our analytical problem, since in the mercuric acetate precipitate we have substances that are for the most part allied to the protein decomposition products for which methods of analysis have been devised; in the filtrate we have basic substances of a fairly uniform type for which also analytical methods are in existence.

Theoretically, then, the problem, while complex enough, should be capable of solution. In practice, however, we encountered many difficulties, and these were of such an acute nature that for the past three or four years we have spent nearly all our time on the development of the existing methods of protein analysis with the view of rendering them more readily applicable to the project in hand.

It may be of interest to point out the nature of some of these difficulties. For many years it has been customary, when one must separate a mixture of mono-amino acids and basic amino acids, to employ phosphotungstic acid to precipitate the basic substances. The precipitate can be readily decomposed by barium hydroxide and the bases quantitatively recovered. The excess of reagent can be equally readily removed from the filtrate which should then contain nothing but the mono-amino acids. This procedure was therefore used in our work on the extract from alfalfa. When the voluminous precipitate was decomposed in the usual way we were somewhat disconcerted to find that a considerable part of the nitrogen in it could not be recovered from the insoluble barium phosphotungstate. Evidently phosphotungstates of substances were present that were not attacked by barium hydroxide, and extensive and uncontrollable losses of nitrogen therefore occurred. A few sad experiences of this nature convinced us that phosphotungstic acid must be used to precipitate these bases only if no better method could be devised.

Another source of difficulty was the highly pigmented substances in the extract. Some of this annoying material found its way into nearly every fraction, and we seldom had the comfort of working with colorless solutions.

The most serious difficulty of all was, however, a feeling of uncertainty regarding the details of the methods of analysis that were available. The great experience of one or two of the workers on our staff with the analysis of proteins was indeed a material help, but we felt that a detailed study must be made of many points before we could attack the analysis of plant extracts with confidence.

The results of an analysis of the simpler nitrogenous constituents of an extract of alfalfa leaves may be mentioned as an illustration of the inadequacy of these methods. In spite of the greatest care we were able to account for only approximately 30 per cent. of the solids and 55 per cent. of the nitrogen of this extract in the form of well-characterized products weighed in crystalline form. While it is probable that a considerable part of the undetermined nitrogen belonged to some of these same substances that we were unable to bring to crystallization in a form fit for weighing, it is clear that much of the nitrogenous material in this extract is of as yet unknown nature.

One very important conclusion became clear from this investigation. In recent years there has been a tendency to apply indirect methods of analysis to plant ex-

tracts. These methods are founded on the behavior of certain substances with specified reagents. For example, when arginin is heated with strong alkali, one half its nitrogen is split off as ammonia, and from the amount of ammonia so formed one can calculate the amount of arginin present with considerable accuracy. This method works fairly well in the relatively simple mixture of bases derived from the hydrolysis of proteins. When it is applied to a plant extract the assumption is made that no other substance is present that is decomposed by alkali to liberate ammonia, an assumption that, in our opinion, is hardly justified. As a result of our experience, we feel that few indirect methods of this type can be safely applied to these complex and largely unknown mixtures. The only adequate criterion for the presence of a substance is a crop of crystals of the substance itself, or a derivative of it, that can be subjected to detailed analysis and proper identification. Indirect methods have their place and are frequently of immense value, but they can be applied only when a demonstration is provided that there is no interference from other constituents of the mixture.

Our general dissatisfaction with the details of base analysis, as usually employed, led us to an extensive investigation of these methods. In the hope that a higher degree of precision might be attained when simple mixtures were taken for analysis we turned to proteins, since these when hydrolyzed yield, so far as is known, only three basic amino acids, histidin, arginin and lysin. It further happens that these three are, with respect to their behavior towards silver salts, typical representatives of three of the four main classes of organic bases already mentioned.

I may pass over the details of these investigations, since they have little interest to those not engaged in this type of work; the net result has been that we have brought the methods for the quantitative analysis of the basic amino acids yielded by proteins to a point where a very high degree of precision can be attained. This work has an intrinsic value aside from its application to the analysis of plant extracts. The physical chemists now require highly accurate determinations of the basic and of the acidic amino acids derived from proteins for the further development of the theory of proteins. We believe that our methods provide the requisite degree of accuracy as regards the basic amino acids, and the work of Dr. D. B. Jones,[9] of the protein and nutrition division of the Bureau of Chemistry and Soils, has recently supplied modifications of the methods for dealing with the acidic amino acids which are capable of yielding highly accurate results.

Although our study of the methods of protein analysis has not yet been brought to a conclusion, it had reached a point some time ago where it seemed desirable to return to the subject of leaf cell analysis. We wished to select a material that would fulfil a number of requirements that our previous work had shown to be of importance. The alfalfa leaf is very small, and as our earlier work was done upon the plant as cut with a scythe, leaves and stalks were both included in the material examined. For the new work a large leaf was desirable. The extract was to be made by plunging the leaf into boiling water so as to stop enzyme action and kill the cells immediately; a thin leaf was therefore needed. Furthermore, we desired to have leaves from plants all of one fixed variety, of the same age, grown under the same conditions of nutriment and reproducible from year to year.

No plant appeared to fulfil these strict requirements so well as the tobacco plant. We have in Connecticut a branch of the experiment station devoted to the study

[9] D. B. Jones and O. Moeller, *J. Biol. Chem.*, 79: 429, 1928.

of tobacco, and this branch is in a position to supply material of a highly constant type grown year after year under precisely similar conditions and under expert supervision. Furthermore, in view of the economic importance of the tobacco crop in the state, the station looked with great favor on our suggestion and offered the most generous assistance.

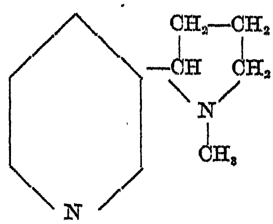
We have therefore been engaged for some time in a preliminary study of tobacco. This study has, to the present, been devoted almost wholly to the solution of the special problems that arise from the presence of the volatile alkaloid nicotin, and to devising methods for the determination of different forms of nitrogen in the presence of the nitrates that are usually found in considerable amount. I shall not weary you with a detailed report of these investigations. I wish only to draw attention to two points since they illustrate our method of approach.

Although it is widely believed that the tobacco plant normally contains a considerable proportion of nitrate, an examination of the literature revealed that the evidence for this is based, from the qualitative side, upon color reactions, while the quantitative estimations of the nitrate have always been carried out by indirect methods that were not entirely above criticism.

We wished first to prove that the substance in the leaf that has been regarded as nitrate was in fact this substance. A specimen of tobacco was therefore treated with an excess of calcium hydroxide, was then dried and extracted with alcohol, whereby we hoped to extract all the nitrate as calcium salt. The alcohol extract was evaporated, the residue was dissolved in water, filtered, and was then treated with nitron, an organic base that forms a very insoluble crystalline compound with nitric acid. Pure crystalline nitron nitrate was readily secured, and the quantity found corresponded to over 90 per cent. of the nitric acid that the indirect quantitative methods had indicated was present in our original specimen of tobacco. This made it certain that we were really dealing with nitrates in this plant.[10]

The tobacco plant contains very considerable amounts of nicotin, and this substance is distributed throughout the plant, in leaf, stem, root and flower. As the ovaries in the flower develop, the proportion of nicotin in the ripening seed diminishes, and the fully matured seed of the plant is, so far as we have been able to detect, entirely free from nicotin. When matured seed is scattered on blotting paper, moistened with distilled water and kept at the right temperature and humidity for about ten days, a sprout from 2 to 3 cm long develops. The sprouts can be removed from the seed and an extract of them prepared. Such an extract was found, by the customary indirect method of analysis, to contain nicotin in an amount equivalent to 0.3 per cent. of the dry weight of the material. As this was a matter of too great significance to admit of uncertainty we prepared a considerable quantity of the sprouts, isolated the nicotin from them and converted it to the beautifully crystalline dipicrate which was identified beyond possibility of doubt.

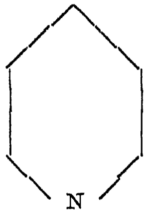
Inasmuch as the sprouts grew entirely upon the stores of food laid up within the seed, it is clear that the nicotin we prepared from these sprouts arose from precursors within the unsprouted seed; no outside source of nutriment was available to the embryonic plant. Now nicotin possesses a highly characteristic mo-



Nicotin

[10] H. B. Vickery and G. W. Pucher, *Ind. and Eng. Chem., Analytical Edition*, 1: 131, 1929.

lecular configuration. It is formally de-



Pyridin

rived from the extremely stable nitrogenous substance pyridin that was first encountered in the so-called Dippel's oil, an oil prepared by the distillation of bones, and is also found among the products of the distillation of certain kinds of coal. It seems reasonable that among the substances in the seed of the tobacco plant there must be one that contains this interesting ring structure.

In the search for this precursor of nicotin our thoughts naturally first turned to the proteins of the tobacco seed. Although there is no known constituent of proteins that contains the ring structure of pyridin, it is by no means beyond the bounds of possibility that such a structure may occur in some proteins, particularly the proteins of the tobacco seed. We have therefore, as it were, turned our laboratory clock back thirty years or more and are again studying the proteins of a seed according to Osborne's classical methods. We found that the tobacco seed contains a globulin that could be readily obtained in a beautifully crystalline form. Inasmuch as not many more than a dozen vegetable proteins have hitherto been described in the crystalline condition, and these for the most part by Osborne himself, this result was most gratifying. Our studies of the newly isolated protein are now being carried on. Whether or not it contains the desired precursor of nicotin, the investigation of so well-characterized a protein is itself a matter of interest.

I have endeavored to present a brief story of the activities of the laboratory at New Haven. In considering these matters while preparing this discussion, I have been struck by the painful slowness with which results of a worth-while nature are secured. In a narrative stripped of discussion and explanation it would be relatively easy to tell you in ten minutes of all that we have actually accomplished in a period of ten years. Such a narrative would, of course, leave out of consideration the innumerable false starts and actual failures, and the indescribable feelings with which one watches a month's hard work drip out of a cracked beaker and run to waste across the laboratory table. It would leave out, also, the hours of study and concentrated thought that precede the birth of an idea. But perhaps most important of all, it would leave out entirely the joy that one takes in the rounding out of a new hypothesis, the crystallization of a long-sought substance or the discovery of a new fact.

Scientific research is like a journey across a broad country. One travels now up, now down, and sometimes one descends very deeply indeed into interminable valleys; but occasionally one reaches an eminence from which a wide view of the whole can be obtained. Such is the reward for effort.

In conclusion may I quote the last few sentences from the last paper prepared by Dr. Osborne for publication.[11]

> It must not be forgotten . . . that the real chemistry of cells is far too complicated to be dealt with adequately by a study of the constituents of the mixture in the fluid obtained from them. Microscopic examination of the original cells shows them to be complex structures containing chloroplasts, nuclei, vacuoles, etc., each of which parts implies a different chemical structure. I fear that for a long time to come much will still remain to be learned about the chemistry of the cell, but if, in the meantime, we can extend our knowledge of this subject it may save us from many erroneous conclusions based on incorrect results that were obtained without sufficient appreciation of the real nature and complexity of the problem.

[11] T. B. Osborne, *Leopoldina, Ber. kais. Leopold. deut. Akad. Naturforscher Halle,* 4: 228, 1929.

THE ULTRASCOPIC VIRUSES FROM THE BIOLOGICAL STANDPOINT

By Professor E. W. SCHULTZ

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THOUGH most people have never experienced the thrill of a microscopic visit to that vast world of miniature plants and animals which surrounds us everywhere, few nowadays question the existence of microbic life. The term "germ" has become a household word. In the evolution of living forms these simpler precursors of higher living forms are probably to be expected. To the biologist they represent the simplest units of life which he can study under his microscope. Indeed, the average biologist does not anticipate much of interest to him below the range of his instrument. This is easy to understand if we bear in mind that with a good microscope one can still discern by direct illumination bodies as small as 0.25 of a micron (or 1/100,000 of an inch) in diameter and that these just discernible living bodies present little for structural analysis. Indeed, with optical facilities which enable one to see and study cells of this minute size, a sort of doubt has grown up that anything much of importance to a biologist could lie outside the range of his ordinary optical devices. Assuredly, how could there be much when the smallest cells still within range of his instruments present so little actually to distinguish them from non-living spheroids, presenting as they do no discernible nucleus or other distinctive structural features, only the visible evidence of their proliferation and of their chemical activities bearing witness to their living nature?

While certain good reasons have tended to support the supposition that nothing of significance could lie below the range of microscopic vision, the discovery by Iwanowski thirty-seven years ago that the virus of tobacco mosaic disease, a transmissible disease attended by a peculiar mottling and dwarfing of the affected plants, is capable of passing the pores of a fine porcelain filter, at any rate suggested the probable existence of life much below the range of our best optical instruments. Indeed, Beijerinck, who five years later rediscovered the filtrability of this virus, actually postulated the agent as a living contagious fluid (*contagium vivium fluidum*), a deduction not so illogical if we remember that the colloidal state of matter was then not as generally known as now.

While these studies on mosaic disease of the tobacco plant served to open the door to an entirely new group of infectious agents, exemplaries of the group have come to us in largest numbers from studies on the causal agents of various animal diseases. In the year that Beijerinck in Holland rediscovered the filtrability of the virus of tobacco mosaic disease, Loeffler and Frosch in Germany, while engaged in an endeavor to separate a toxic substance for immunization purposes from the lesions of foot-and-mouth disease of cattle, discovered that the agent itself of this disease is capable of passing the pores of fine porcelain filters. Also in the same year Sanarelli in South America discovered the filtrable nature of the virus responsible for a strange malady among his stock rabbits known as infectious myxomatosis of rabbits. These interesting observations made in the course of a single year in different countries naturally prompted similar inquiries into the causation of a number of other diseases the etiology of

which had hitherto remained uncertain or entirely unknown. More than thirty such filtrable agents are now known to be responsible for infectious diseases. Among them are the agents of such familiar diseases as smallpox, cowpox and pox diseases of other animals, rabies, poliomyelitis, fowl plague, cattle plague, leukemia of chickens, sarcoma of chickens, hog cholera, distemper of dogs, encephalitis of certain fur-bearing animals, certain diseases of insects and certain diseases of fish. Recent additions to the list include the bacteriophage, the virus responsible for so-called "parrot fever" or psittacosis, and yellow fever.

As important as many of these ultrascopic viruses are from the medical and economical standpoints, it is not my purpose to enlarge on these aspects of the general problem which they present. Quite apart from the urge for practical information, which the investigator naturally can not disregard, the ultraviruses present much of interest from the standpoint of purely biological research. What are they? Are they living agents, or are they perchance nonliving agents resembling only outwardly, as they spread from host to host, a truly living parasite in the transmissible effect which they produce? As living agents they would certainly challenge the interest of any biologist, for what biologist is not interested in the most primitive forms of life? Should they be inanimate in nature, interest in them from a biological standpoint would not diminish, for the attention of the biologist would then merely shift to the strange phenomenon which causes a virus-tainted cell to regenerate the selfsame agent which induced the original disease process. The biologist would then want to know what starts off such a pernicious cycle in nature, and also something regarding the precise mechanism underlying such a disturbance. It can be seen, then, that, whatever the exact nature of these agents may be, they present considerable in the way of interest from the purely biological standpoint.

Let me sketch briefly some of the more important characteristics which tend to set the ultrascopic viruses and the diseases which they produce off in a class by themselves.

Properties of Ultraviruses

Ultrafiltrability

To say that a virus is filtrable in the sense that it passes through the pores of an ordinary porcelain or kieselguhr candle does not tell us much as to the actual size of the agent passing the filter. On the one hand, one can not be certain that the agent passing such a filter is actually of subvisible dimension, and, on the other hand, one can not always be certain that a negative result precludes the presence of a virus. A number of factors, such as the composition of the filters, their electrical charge, the pressure used, the nature and reaction of the menstruum, etc., may greatly influence the results of any filtration experiment, particularly when earthen filter candles are used.

While filtration through ordinary filter candles tends to yield a rough separation of microscopic and submicroscopic forms, filtration through graded collodion membranes, the pore size of which may within certain limits be controlled, enables one to determine with a fair degree of approximation the physical magnitude of the agent under observation. Even under these conditions it is difficult, if not practically impossible, to make accurate measurements of the size of virus particles. This difficulty is made more real by virtue of the fact that none of these agents with the possible exception of the bacteriophage has been obtained in even a relatively pure state, free of protein and other aggregates derived from the host, which in themselves greatly disturb the results of any filtration experiment. However, despite these obstacles, some interesting and, I trust, significant measurements

have thus far been made by means of these graded collodion membranes. While the results of these measurements must be regarded as approximations only, they nevertheless tend to confirm the suspicion that in some of the so-called filtrable viruses, at any rate, we have a group of agents whose organization, if they be living, must be appreciably simpler than that of the smallest bacterium known to us, indeed so much more primitive that it is difficult to visualize constituent functional parts in such cells, if they may still be regarded as cells.

The virus on which the greatest number of measurements have been made is the bacteriophage, an agent discovered about fifteen years ago which produces a transmissible disease of bacteria, associated generally with an explosive dissolution of the bodies of the affected organisms. A mere trace of a dissolved bacterial culture containing this virus is sufficient to set up the diseased state in a new culture. Thousands of passages may be made in this manner from one dissolved culture to a fresh culture without the slightest diminution in the final concentration of the lytic agent, a fact which compels us to conclude that the agent multiplies at the expense of the bacteria it dissolves, by virtue of which it bears the earmarks of a true virus. Because of the tremendous interest which this discovery aroused, particularly with reference to the possible nature of the agent responsible for this phenomenon, many investigators have made a study of the properties and behavior of this interesting filter-passing agent. Indeed, the relatively simple conditions under which the nature of this virus could be studied have offered additional impetus to the study of virus problems in general, with the result that much of the work carried out in recent years on viruses in general can be credited in a large measure to the stimulus which has grown out of the studies on the nature of the bacteriophage. As might have been anticipated at the outset two schools have grown up relative to the nature of this agent (this applies to other ultrascopic viruses also), one maintaining that it is of a living nature, the other that it is non-living in nature. Those who dispute its living nature base their stand, in part at least, upon the inordinately small size of the 'phage particle. Not content with the earlier approximations of 20 to 35 $\mu\mu$,[1] more recent investigators have crowded it into progressively lower orders of magnitude. Most recent measurements, including some made in our laboratory, place it in the neighborhood of 5 $\mu\mu$. Expressed in another way, it would require more than two thousand of these 'phage particles placed together in one plane in a circle to bring them within the range of visibility. Whether or not this infinitesimal size is in itself sufficient to place this particular virus in the realm of non-living substances, I, for one, will not venture to say. I shall return to this question later.

When we review measurements made on other ultrascopic viruses, particularly those responsible for certain animal diseases, comparatively few results present themselves for consideration. The reason for this probably lies in the fact that the obstacles which have to be overcome here are much greater than those which apply to the bacteriophage. Bacteriophage suspensions present comparatively little in the way of associated colloidal matter to disturb the results. Even these may be removed without great difficulty, and it is largely because of this fact that succeeding investigators have been able to assign progressively lower orders of magnitudes to the bacteriophage.

[1] $\mu\mu$ = millimicron = 1/1,000 of a micron. If we remember that a micron is equal to 1/25,000 of an inch or 1/1,000 of a centimeter, and that a spherical body 0.5 μ in size may just be seen nicely with a good microscope, we can picture roughly at least the size of a $\mu\mu$.

In the case of plant and animal viruses, by far the larger portion of a virus suspension is made up of disintegrated host tissue substance. This is easily understood if one remembers that in preparing the virus suspensions one grinds the affected tissues containing the agent to a finely divided state, and it is this mixture which one is compelled to work with in a study of these viruses. The foreign material with which the virus is associated tends to clog the pores of even the coarser collodion membranes, reducing their size, which in turn has the effect of giving to the virus a larger particle size than that which it actually possesses. The disturbance caused by this colloidal matter is not due solely to the physical aggregations represented, but in a large degree to the electrical charges which these aggregates bear, causing the viruses also bearing electrical charges to become strongly adsorbed to larger aggregates.

While some progress has been made in effecting a partial separation of this foreign matter from the virus suspension, this has not been sufficient to affect the problem materially. Nevertheless, in spite of these difficulties some suggestive observations have been made on the viruses in question. Enough has been learned to tell us that here also we may be dealing with agents whose physical magnitude may perchance not greatly exceed that of the bacteriophage virus just referred to. Indeed, one investigator has estimated the size of the virus of fowl plague at about 2.5 $\mu\mu$, a figure which may possibly be a little too low for this virus, taking into consideration more recent investigations. Another investigator found the viruses of cowpox, of rabies and herpes-encephalitis practically as filtrable as the bacteriophage. According to still another set of measurements reported, the virus of foot-and-mouth disease and also that of chicken sarcoma seem to lie well below 100 $\mu\mu$. Measurements made by us on the virus of infantile paralysis suggest that this agent lies somewhere below 100 $\mu\mu$. This work is still in progress, and it is entirely possible that further results with more favorable virus suspensions will point to an even lower order of magnitude.

The particle size of the virus of tobacco mosaic disease has been found by Duggar and Karrer-Armstrong to be comparable to that of a 1 per cent. hemoglobin solution. These results suggest that the magnitude of this virus may not exceed that of the bacteriophage.

It is probably quite unnecessary for me to stress the importance and significance of the observations reported. Certainly, the results reported thus far point quite definitely to a new group of agents clearly separable from the microscopic forms known to us as bacteria. They must either represent exceedingly primitive forms of life or belong to a class of agents analogous to ferments. That they are not just submicroscopic bacteria seems certain.

Cultivation

Another reason for regarding the viruses as unrelated to bacteria lies in the fact that despite repeated attempts to cultivate them on lifeless artificial culture media they have never been cultivated in this manner. While there have been a few successful attempts reported, not one of them has been sustained by subsequent workers. Certain viruses (cowpox, herpes) have, however, been cultured in tissue cultures, that is, in the presence of living, growing tissue cells. Thanks to the excellent work of a number of investigators, particularly of Carrel and of Lewis and Lewis, the art of cultivating tissues *in vitro* has reached a high degree of perfection. Not only is it possible to cultivate successfully tissues of such low order as mesenchyme (connective tissue cells, etc.), but also more specialized tissues,

such as endodermal and ectodermal cells, liver cells, skeletal and smooth muscle cells, nerve fibers, etc. Not only normal, but cancer cells from certain tumors of rats, mice, dogs, chickens and of man have also been successfully cultivated *in vitro*. While the procedure is a little exacting, it nevertheless promises to yield itself well to a solution of some aspects of the virus problem. Strangely enough only a few investigators have made use of this avenue in their approach to the virus problem. Thus far, only a few viruses have been cultured in this manner. The virus of fowl plague has been cultured in tissue cultures of bone marrow; the virus of Rous chicken sarcoma in cultures of leucocytes and embryonic tissue cells, and vaccinia virus in a variety of tissue cultures.

Tissue Affinities of Viruses

Not only do the ultrascopic viruses seem to require living cells for their propagation, but many appear to be highly selective not only with regard to the species of animal they will attack, but also with regard to the particular tissue they pick out. The virus of poliomyelitis not only limits its attack to man and monkeys, but exercises a decided selective affinity for nervous tissue, affecting primarily the motor nerve cells in the medulla and cord. Other viruses are more or less equally selective in picking out the animal species and particular tissues. Some are more selective than others, but all of them exhibit a well-defined affinity for certain host cells rather than for host tissues in general.

The viruses not only tend to exercise considerable choice in the type of tissue cell they invade, but many of them exhibit a decided preference for young growing cells. The bacteriophage almost without exception produces its effect on young growing bacteria. The phenomenon of lysis and regeneration of the principle is brought out most clearly when the lytic agent is added to a young, actively proliferating culture. The activity of plant mosaic virus is manifested only in the younger leaves of the plant. The implantation of cowpox virus in anti-smallpox vaccination is, as you know, facilitated by scarification, an operation which is promptly followed by a regeneration of lost tissue and therefore the appearance of young, rapidly dividing cells. Once a virus has become implanted it may by cell destruction or other means bring about the necessary proliferation of quiescent body cells to meet its demand for young impressionable cells. Such growth-stimulating action is noted particularly in a disease known as chicken sarcoma, a cancerous affection in which proliferation of certain tissue cells takes place in a manner analogous to that observed in other malignant tumors. The addition of a bacteriophage to a young bacterial culture serves to speed up greatly the rate of bacterial multiplication. The cell injury which apparently accompanies the growth-stimulating action in the latter instance is accompanied by a marked influx of water into the cell, causing it to burst much in the fashion of a toy balloon. As a newspaper reporter has aptly put it, in describing the theory of a certain investigator, "The bacteriophage plunges bacteria to an early death as the result of the *fast living* and *too much drinking* which it induces." (While this tells us nothing regarding the exact nature of the agent responsible for this pernicious influence on bacteria, it does convey a vivid picture of the more obvious consequences which follow the addition of bacteriophage to impressionable organisms.) Apparently two forces operate in a virus disease—one stimulating the cell, the other destroying it. In certain virus diseases, as in chicken sarcoma, contagious epithelioma, fowl leukemia and in warts, growth-stimulating forces predominate; in others, such as smallpox, foot-and-mouth disease, herpes, poliomyelitis and

the lysis of bacteria under the action of a bacteriophage, the destructive forces overshadow the cell-stimulating forces. This has the effect that in certain virus diseases we may observe tumor-like proliferation of cells, while in others only cellular débris may mark the places where normally placed tissue cells once existed. While different viruses tend to influence cells more in one direction than the other, it is apparent that in either case the effect is on certain selected cells which the virus presumably actually invaded. While bacteria may flourish in large numbers in the interstices of a tissue, they rarely invade the tissue cells themselves.

Inclusion Bodies

Viruses differ from bacteria not only in their preference for an intracellular existence, but also in that many of them give rise to peculiar formations within the affected cells known as inclusion bodies. In some virus diseases, such as rabies and cowpox, these bodies appear only in the cytoplasmic portion of the cell; in other diseases, such as herpes simplex and Borna's disease of horses, only in the nucleus of the cell, while in still other infections, such as smallpox, in both the cytoplasm and nucleus of the affected cell. These may be round, oval, pyriform or irregular in shape, homogeneous or granular and either acidophilic or basophilic in their staining reactions. Their nature is a disputed question. Some of the earlier investigators regarded them as protozoa, picturing them in various stages of an elaborate life cycle; others have come to the conclusion that they represent a class of micro-organisms which become characteristically coated with cellular material and have accordingly named them "Chlamydozoa" or cloak animals; a few investigators consider them as more or less solid aggregations of the virus corpuscles themselves. The general trend of opinion at the present time seems to be that these inclusion bodies represent primarily reaction products derived from constituents of the cell rather than the agent itself, though as certain recent investigations have conclusively shown, the virus itself may be prominently represented within the inclusion body. Whatever the exact nature of the inclusion body may be, there can be no question that its presence is definite evidence of a virus infection. On this rests one of the most important procedures in the diagnosis of rabies in which the finding of so-called Negri bodies within the nerve cells in the brain constitutes a positive diagnosis of the disease. Not all virus diseases, however, are accompanied by these cellular inclusions. Poliomyelitis is a disease in point. It appears that in poliomyelitis the cytolytic changes move along too rapidly to permit reaction products to form within the cell. Exceptions of this sort are, however, relatively uncommon, and it may be that suitable methods still remain to be worked out for the demonstration of similar reaction products for the diseases in which these exceptions seem to exist.

Immunity in Virus Diseases

A significant difference between ultravirus and bacterial diseases is also noted in the relative duration of the immunity which follows recovery. While recovery from certain bacterial diseases (typhoid) tends to leave one with a more or less durable immunity to the same disease, this is not true for the vast majority of bacterial infections. Repeated reinfections with the same bacterial species during the course of an individual's lifetime is not a rarity. In virus diseases, on the other hand, the contrary is the rule. While exceptions may be cited, virus diseases generally leave those fortunate enough to recover with a solid and lasting immunity, an immunity which is real and not merely relative. Why then is there this strik-

ing difference in the solidity and durability of the immunity in these two general classes of infectious diseases? Is the difference to be explained on the ground that the defense mechanism of the cell is more profoundly stimulated by a virus than by a bacterium, or does the defense mechanism differ radically for the two general groups of agents, the one being relatively more effective in carrying out its particular function than the other? No satisfactory answers to these questions are at hand. Recent observations suggest that the acquired immunity against virus diseases may rest in part at least on a persistence of the virus in the tissues of the host following recovery, in other words, may consist of an infection immunity analogous to that which exists in a person, or an animal, infected with the spirochaete of syphilis. It is well known that a syphilitic individual can not be superinfected so long as he harbors the organism. Not until he has been actually cured of the disease, and only then, does he become susceptible to reinoculation. This possible explanation of virus immunity finds support in recent observations which have been made on the persistence of viruses in the tissues of animals following recovery. The blood of a horse has been found infectious seven years after an attack of pernicious anemia; the virus of foot-and-mouth disease has been recovered from a bull six months after recovery; vaccinia virus has been recovered from the tissues of experimental animals several months after infection and recovery. The virus of poliomyelitis has been found in monkeys five months after recovery from an acute attack of the experimental disease. Bacteria which survive the lytic action of bacteriophage and grow up as secondary resistant cultures not infrequently continue to flourish from generation to generation in intimate association with the bacteriophage. Once freed of the principle they tend to revert to susceptible forms again. Other examples might be cited. Of significance also are the observations recently reported by Olitsky and Long on vaccinia immune rabbits, who found that the acquired immunity following inoculation disappeared in these animals soon after the disappearance of the virus from the tissues of the host. From the various observations cited it would seem, therefore, that acquired immunity against virus infections may swing, in part at least, on a persistence of the virus in the tissues of the recovered individual. What keeps the virus in check within the host is not exactly clear, except that we know that the serum of such an immune individual contains antibodies capable of inactivating the virus. Strangely enough the antibodies which seem to be responsible for holding the viruses in check apparently accomplish this not by actually effacing the agent, but by rendering it incapable of injurious action. We may assume that it is not necessarily actually destroyed because inactive serum-virus mixtures may within certain limits of time be rendered active again by well-recognized procedures, but this brings me to the next chapter in the development of my theme, namely, the antigenic behavior of the ultraviruses.

Antigenic Properties of Ultraviruses

If we stop to analyze antigens[2] as a group, we find that they may be divided into two general classes—those which, like toxins and ferments, stimulate within the host the formation of specific neutralizing antibodies; and those which like bacteria and other complex proteins stimulate the formation of antibodies (cytolysins, agglutinins and precipitins) whose function seems directed solely

[2] An antigen is any substance which injected parenterally into an animal will stimulate the formation of specific antibodies—substances which react in one way or other with the antigen.

towards an elimination or removal of more complex foreign proteins from the body. While no sharp line has been drawn between these two general classes, certain fundamental differences seem to present themselves which warrant an attempt to classify ultraviruses in part on the basis of their antigenic behavior. Such studies have been undertaken in a number of laboratories, including our own, with significant results. The sum total of these studies seems to indicate clearly that the antibodies stimulated by the ultraviruses resemble much more closely antitoxins and antienzymes in their nature than they do the antibacterial and the antibodies which are formed against other complex proteins. Expressed in another way, they seem to belong to the first rather than the second class of antigens. Like the neutralization of the soluble toxins formed by the diphtheria bacillus by its antitoxin, a mechanism which has to be distinguished from that which has to do with the elimination of the diphtheria organism itself, antibodies formed against the ultraviruses function merely as inactivators or neutralizers of the virus. In this inactivation the virus does not appear to be actually destroyed but merely rendered inert because of some sort of union which takes place between the virus and the antibody. As in the union of diphtheria toxin with its antitoxin, the union between a virus and its antibody may, as I have already indicated, be broken up with the result that the active virus, as well as the antibody, may be set free again. The mechanism is in a measure comparable to that of an ordinary chemical reaction in which the resulting compounds may be resolved again into their constituent substances. This dissociative effect, which can for a time at least be realized, is something not realized in the reactions which may take place between bacteria and their antibodies. It will be seen, without going further into a technical subject, that the ultraviruses are distinguishable from bacteria not only in the several respects already mentioned but also in their antigenic behavior. Not only this, but we have in the close resemblance which they bear antigenically to toxins and ferments further evidence of their lowly organization and distinctive properties. I should add, however, that while the latter is true, this does not justify the conclusion that the viruses are actually of the nature of true toxins or ferments. All one can say is that the ultraviruses, because of distinct and singular differences in the chemical and physical constitution, seem prone to elicit an antibody response differing fundamentally from that which is elicited by more highly organized proteinaceous bodies.

Nature of the Ultraviruses

From the facts brought into review we can see that the ultrascopic viruses represent a class of infectious agents whose properties differ in certain important respects from the simplest forms of microscopic life known to us. We have seen that they differ not only in being of a much lower order of magnitude, but also in their inability to grow on lifeless artificial media, in their dependence on and selective affinities for special tissue cells, in the peculiar cytological changes which they induce, in the type of immunity which they give rise to and also in their antigenic behavior. What, then, is the exact nature of these filtrable agents? Do they represent exceedingly primitive forms of life or are they perchance non-living agents of the nature of ferments, hormones or toxins—substances which set up within a living cell disturbances of such a nature that the affected cell is caused to elaborate more of the selfsame agent? Both views are being entertained, and one may, in the present state of our knowledge, argue quite as effectively for one view as for the other.

Possibly the best argument in favor of the living nature of these ultrascopic agents is their transmissibility in series, a phenomenon which one feels forced to associate with a progressive multiplication of the virus particles. It is, however, not necessary to assume that this multiplication can take place only as a result of some sort of cleavage or reproductive mechanism inherent within the virus corpuscles themselves. It is barely possible that such a regeneration might be accomplished through the medium of the host cell deranged in some way by an appropriate agent setting up a disturbance of such a nature as to cause the cell itself to elaborate more of the selfsame principle capable of affecting new cells. While the provision of such a mechanism of virus regeneration would seem an unusual thing to expect of a cell, whether diseased or normal, this possibility is strongly embraced by some investigators. True, there are no satisfactory parallels known to biologists on the basis of which such an assumption can be reasonably supported. That damaged tissues liberate a growth-stimulating principle has been known for some time. In such a scheme of things the newly formed cells are potentially fully as able to liberate this principle on being injured as were the original cells which they displaced. Yet in this scheme we do not have self-perpetuating cell destruction going on hand in hand with that of growth stimulation. Were one able to reconcile in any way the regeneration of self-destructive agencies with that of the biological struggle for self-preservation, it would be a little less difficult to leap the gap which exists between such contrary tendencies in nature. Something which does harmonize with the idea that viruses may be regenerated by the affected cells has been observed in studies on certain ferments. Bordet and Gangou, while working on coagulation of the blood, observed that a given quantity of thrombin not only exercises a direct coagulating action on blood, but also stimulates the production of new thrombin at the expense of materials in the coagulable fluid. A plasma which no longer yielded thrombin spontaneously could be made to yield considerable quantities on the addition of a small quantity of thrombin. Another investigator has found that enterokinase produces a similar transmissible effect in the transformation of inactive trypsinogen into active trypsin. Not only does a small amount of enterokinase serve to activate a given quantity of trypsinogen, but the products of the reaction may serve to activate new quantities of trypsin. These observations, while not strictly comparable to the transmissible effects produced by viruses, nevertheless offer something for our consideration.

The possibility that the ultraviruses may be of a non-living nature tends to be supported also by certain observations indicating that they may be caused to arise *de novo* either naturally or under the influence of certain agencies. A number of investigators claim to have recovered bacteriophage from bacterial cultures previously free of this agent either after allowing them to age under more or less natural conditions or after subjecting them to certain unusual physical and chemical influences. Similar observations have been reported bearing on virus diseases of animals. According to Carrel the injection into chickens of embryonic tissues and certain chemicals, such as arsenic, coal-tar, indol and peptone, produces sarcomas which contain the Rous sarcoma virus. Similar results have been obtained with spleen tissue treated with arsenic *in vitro*. Rivers and Tillett chanced to uncover a new virus by injecting intratesticularly suspensions of ground rabbit testicles from rabbit to rabbit in the course of another investigation. Naegeli has noted the appearance of herpetic lesions in a certain percentage of

patients injected with bacterial vaccines. All these results, however, bear the stamp of chance findings and are, as subsequent investigations have shown, not readily reproducible. Until one can make certain that viruses have not been accidentally introduced from outside sources, conclusions on the basis of such observations must naturally be held in abeyance.

Of particular interest in connection with the question of the nature of ultraviruses are the recent observations of Vinson and Petre on the virus of plant mosaic disease. These investigators were able to precipitate this virus from the juices of the diseased plant by means of aqueous solutions of safranin. In the precipitate the virus is apparently held in an inactive condition but can be reactivated again by removing the safranin by means of amyl alcohol. By further chemical procedures they were able to get the agent in a comparatively, though not entirely, pure state. They concluded from their studies that the behavior of this virus is in many ways analogous to that of a chemical substance.

While there are good reasons for doubting the living nature of at least some of the ultrascopic viruses, there are also excellent reasons for regarding them as animate bodies. Were we better informed as to what actually constitutes *life,* there might not be any cause for controversy as to the nature of the agents under consideration. Since we have no satisfactory answer to the fundamental question of "What is life?" it becomes necessary for us to get on as best we can with the criteria at our disposal, remembering that these may only partially measure the essential attributes of life. We must remember also that the criteria we may see fit to measure by are based entirely upon the behavior of complexly organized living bodies, even though based upon the simplest single cell organisms with which we are familiar. We know nothing whatever regarding the fundamental attributes of the ultimate living or life-giving constituents of the cell. We are entirely uninformed as to how the attributes of these ultimate units differ from those of the living cell as a whole. And this is one place where our method of measuring life begins to break down. That bacteria, at least some of them, may become transformed into filtrable ultrascopic stages and back again to visible forms seems to have become more and more clearly established. So far as we know the attributes of the units in the ultrascopic stage may be totally different from those of the microscopic forms under observation. But I must not allow myself to be carried too far afield. Rather, let us make use of the criteria of life so far as they are known to us. Let us see what they are and to what extent they may serve our needs in the present problem. Probably the best consideration of this question is offered by d'Herelle in supporting his hypothesis of the living nature of the bacteriophage. D'Herelle believes that the essential criteria of life are (1) the power of assimilation in a heterologous medium and (2) the power of adaptation or variability. In applying these criteria to the viruses, the answer to the first question swings on a second, namely, that of the autonomy of the agent under consideration. If it can be proved that the agent in question is actually autonomous—is an agent definitely foreign to the host—then the very fact that it is transmissible in series—that is, multiplies—proves that the agent must possess the power of converting host substance into its own substance, in other words, possesses the power of assimilation. Proofs of autonomy may vary in character. None are easily established. D'Herelle has offered what he regards as at least ten

different proofs of the autonomy of the bacteriophage. I have time to refer only to two which, to me, appear especially significant. If one injects a rabbit repeatedly with a bacteriophage lysed culture, specific antilytic or antiphagic antibodies will make their appearance in the blood of the animal, while the injection of a 'phage-free bacterial culture, whether autolyzed or not, never gives rise to such antilytic antibodies. The bacteriophage, therefore, appears to possess distinctive antigenic properties distinguishable from the antigenic components of the bacterial cell. In other words, antigenically it behaves like an independent autonomous body. Moreover, if we take an antilytic serum so produced and add it to a secondary culture, one in which resistant bacteria and 'phage coexist "symbiotically," and in consequence of which the cultural properties of the bacterium have been profoundly changed, we will not only succeed in inactivating the bacteriophage in the mixture, but we will also succeed in converting the cultural behavior of the bacteria back to their normal state. This "curing action" of antilytic sera on abnormal secondary cultures may well be compared to specific serum therapy in infectious diseases of man and animals. It is an effect which one can easily understand if he regards the bacteriophage as an autonomous agent, foreign to the bacterium attacked. It is, on the other hand, an effect which is difficult to understand when one views the bacteriophage as some abnormal product of the bacterium's own body. What I have said regarding the autonomy of the bacteriophage probably applies equally to other ultraviruses. With the autonomy of a virus fully established, a matter that is more easily affirmed than done, there seems to be no other conclusion left for us to draw than that the viruses possess the powers of true assimilation—one criterion of life. It has seemed to me for some time that the only logical manner for d'Herelle's opponents to attack his hypothesis of the living nature of the bacteriophage would be for them to undertake to test the validity of the hypothesis on the basis of the criteria of life advanced by d'Herelle. How secure is the evidence that the bacteriophage actually exhibits the two basic criteria of life—assimilation and adaptability? What evidence can be amassed to prove that the bacteriophage is not actually autonomous, that the proofs advanced by d'Herelle are more apparent than real? What evidence can be collected to show that the bacteriophage does not in truth possess the powers of adaptation? Strangely enough most of the work of d'Herelle's opponents does not relate to these questions. I can say this with a spirit of full neutrality, for to me the question still remains an open one. In sympathy with my view that the validity of d'Herelle's hypothesis should be tested in terms of the criteria of life advanced by d'Herelle, Dr. Beard, a colleague of mine, undertook to make a careful study of the capacity of the bacteriophage to adapt itself to new environmental conditions, particularly of its ability to adapt itself to the attack of entirely new bacterial species. The results of these studies, which he carried out in a very critical and painstaking manner, forced Dr. Beard to conclude that the bacteriophage possesses the power to adapt itself to new bacterial species only in so far as it may possess at the outset a certain "latent" capacity to attack the new species on which it is being trained. Only in the event a bacteriophage exhibited slight or virtually hidden capacity to attack the new species could this capacity be enhanced by serial passage on the new species to a point where the 'phage more or less energetically attacked the new species. In the absence of such "latent" capacity, adaptation to new bacterial species

did not occur. While he was unable to duplicate the results of certain other investigators with respect to the facility with which 'phages were claimed to adjust themselves to new bacterial species, previously not attacked, there nevertheless still remained unexplained the capacity of a bacteriophage to increase from a very weak to a very strong 'phage. This increase in activity, or increase of virulence, reminds us not only of similar properties exhibited by other ultraviruses, but of similar capacities exhibited by such definitely known living organisms as the bacteria themselves. It is a form of adaptation with which every pathologist is familiar. The question before us is then this. Is this enhancement of the virulence of a bacteriophage based upon the same fundamental law as the enhancement of virulence of pathogenic microbes, definitely known to be living? All we can say is that outwardly the two phenomena resemble each other very closely. Basically they may, for all we know, differ widely.

Some doubt has been expressed as to whether bodies as small as 5 to 10 $\mu\mu$ could still be complex enough to be living. In the first place, it must be remembered that the measurements at our disposal represent only rough approximations. In the second place, as I have already pointed out, we know nothing whatever as to what actually constitutes the ultimate units of life. As Gaskell has recently suggested, "life" may be an "intraatomic quantity." It may, on the other hand, be something that depends upon more complex physical aggregations. Of this we can be sure, that the single-cell organisms we see under the microscope represent in reality quite highly organized forms of life. In them one observes already considerable specialization both in structure and function. The smallest visible cell, with no nucleus discernible, must still have represented within its body a diversity of substances which determine the varied physiological processes we can more or less measure. Hofmeister has estimated that a liver cell contains in all more than 200,000 billion molecules, among them 50 billion protein molecules,[3] 150 billion lipoid molecules and 2,000 billion crystalloidal molecules of lower molecular weight. A cube of 0.1 μ or of 0.001 μ^3 (one thousandth cubic micron) volume, that is, a structure of effective submicroscopic size, could, according to this, still contain 25 million molecules of water, 25,000 colloid (protein) and 250,000 crystalloidal molecules. Though we may acknowledge that a body of just submicroscopic size may still present a fair number of protein and other molecules, when we drop to bodies measuring only 5 to 10 $\mu\mu$, the number of protein molecules which are still possible becomes negligible. A coccus of 10 $\mu\mu$ has been estimated not to contain more than twelve molecules of the size of serum albumin. But why should we disturb ourselves over the question of how many protein molecules may be necessary to establish the simplest living unit? The ultimate unit of life may not hinge at all on the question of whether protein is present or not. For all we know the ultimate principle of life may antedate the simplest protein molecule. It is conceivable that from such primary living units may evolve first the smallest living micellar aggregates; from these primitive aggregates the simpler microscopic cells may eventually evolve; from these in turn the more complex unicellular organisms, and with still further specialization and division of labor these give rise to the simplest multicellular organisms and so on. In such a scheme of evolution it is entirely conceivable that a place could be found for the ultraviruses quite regardless of their physical magnitude. Who can say?

[3] To the protein molecule he gave an average molecular weight of 16,000.

HOW DID WE COME BY ART?

By Dr. WALTER HOUGH

U. S. NATIONAL MUSEUM

PHILOSOPHERS, notably Bacon, have viewed man in his beginnings as a helpless creature. This conclusion may possibly be inaccurate, but it does not require an effort of fancy to portray early man as bereft of superficial graces. Man had not the finish bestowed by nature in exquisite beauty on insignificant organisms. He seems to come upon the horizon of life as an afterthought, with beetling brows and rough, dark, hairy skin, a very ugly duckling.

He is provided with strength of body and cunning of brain, serving to put him first in the competition of nature and urging him forward to the culmination when he shall have all things. But in his early stage we do not know that he appreciates his surroundings of natural beauty, nor is it imaginable that he perceives such things as flowers, the brilliant plumage of birds, their songs, or the lovely tints of wet sea shells.

Man is thought to have emerged from a gnarled stem of ungraceful mammals and surely destined from the beginning to make his own way to the decorative perfection which ages of development had given to other animals. His incompleteness is still striking; he intrudes and devastates, yet looks forward to when the scars will be healed, hundreds of millenniums in the future.

In the past we must see him as tentatively feeling his way toward the secrets of his relations to his surroundings in the visible world, the first animal that grasped the keys that would open a never-ending progress. Why and how he did this we would like to know, fascinated, but feeling that these questions can never be answered.

We know, however, that from these fertile beginnings he would build art exterior to himself, a vast realm that nature never knew, exceeding anything ever touched by life, and foreign, so far as we with our limited understanding may guess, to the processes of that mysterious force animating living beings.

In this he would arrive at, by other incentives, the clothing of his ideas as nature decorates her life forms. It is a fair theory to put forward that man in clothing the invisible world with symbolic dress began the long course of art. Nothing exists to show the faint beginnings, what they were like or in what order they proceeded from the inner consciousness of his being, yet somewhere along the line of what seems almost insensible progress the germs are tangibly revealed.

The expression of feelings by muscular movements in figured facial and bodily changes recognized by onlookers as signs of a mental state is universal in the animal kingdom. The old observation that "actions speak louder than words" may be applied here. Out of the animal stage in which such actions are considered psychological emerge the gestures of man taken to be symbols connoting ideas and in effect fundamentals preceding and developing with language. It is evident that gestures universally accompany the complex of speech as a shadow aid, and that they slowly and with difficulty lose their importance.

There is a long period of gesture symbols during which the way is prepared for other forms. Work with the hands in stone, wood, skin, bone, ivory and other naturally occurring materials prepares the media for the recording of art. Without media the groundwork for art is non-existent. The importance

of media is seen to be great in respect to the scope and character of art.

In the order of forms and surfaces art has progressed to the two great divisions—sculpture and decoration. Nature furnished unconsciously the agents by which animals should function to procure food, shelter and the like. By unconsciously is indicated inheritance, development, piling up of habits from experiences, and the vast, mostly unknown part filled with the results of the interaction of life and environment. At some line of fusion man breaks away from the constraints of the intimate surroundings and begins to use extraneous aids to his physical and mental complex. Here at the beginning of arts which are regarded as man-like bed rock is reached.

Theoretically, this period marks the entrance of form as a human contribution to art. Practically, the first expressions of form preserved in enduring flint in the controversial Eolithic period are humanoid only and not to be judged by any conceived tenets of art or even utility, but no doubt satisfying to the Eolithic being, himself mostly a natural product, as conforming to the shapes riven out by usual causes.

With the pre-Chellean and Chellean comes a half natural, half artificial implement with the idea of mass and the beginning point, a feature so important practically and ideally to future arts. From this apparently rapid development of arts, but really of extreme slowness, comes the procession of increasingly concise forms shadowing forth sculpture. Surviving hard materials demonstrate the use of antler, bone and ivory, requiring other freer methods of work, suggesting a wider range of forms which would emerge into the round.

From this point we have predetermined progress that at intervals rose high and again to a low state, yet in essence a real series of advances. Somewhat anomalous developments took place, as that characterizing the school of artists of cave painting in France and Spain whose virile products have formed the life work in presentation by the Abbé Breuil and other distinguished archeologists.

Unique and presumably fostered by some unknown genius, this school of decoration comes into view out of its time and fades away for millenniums till slow development brings in corresponding phases at the proper point in the general line of art. There is nothing in the climax of cave art to show a progress in which symbols played a developmental or originating rôle, despite the thought that paintings were symbols, or rather had a symbolic meaning. For this reason it may be asserted that elemental symbols as discrete units came only with a considerable progress in culture. At early stages symbols had no audience and thus could not have the currency given at a later period when cooperative men had come on the scene. The philosophical view of the symbolism of all things extraneous coming under the purview of human consciousness is not here considered.

Symbols are the shorthand of ideas, the first terms of an equation which reaches an intangible solution in the mind. They are foci for crystallization of thought, human artifacts whose intent is suggestion, which are meaningless to the uninitiated but become the ratiocinative media of the human race. Symbols inaugurate decorative art. They have first currency apparently at a point in culture where abstract ideas can be appreciated.

The idea of property emerges as one of the early manifestations by man of an interest in outward things. While an early workman might not extend the idea of property to flakes struck off in the manufacture of an implement or to rejectage due to any other arts, yet the

finished product becomes his own. If at this state of comprehension the artifact is to be recognized as personal property by others it is logical to surmise that the owner would put his mark on it. This mark is recognized as an early symbol.

In the Old Stone Age the criterion of "mine" would doubtless be a proto symbol revealed in some color, flaw or even habit of flaking which would identify the object. Necessarily we have nothing distinguishable in the stone artifacts that have fallen ages ago from the hands of their owners and there remain none of the perishable elements of social life surviving upon which to note marks or symbols which may have been used.

The steps in psychological phenomenon made by man in producing such simple marks as the circle, square or four-arm cross are perhaps unknowable, falling no doubt into the limbo of unanswered queries as to the origin of many things wrought by the mental equipment of the coming man being.

Ingenuity is no answer because that trait refers to work with things close to the material world. The most that may be said is that at the proper stage these apparently simple marks seem to flash out without preparation or perceptible preparation in anything that has gone before. This is not regarded as dealing with the obscure question of independent invention which comes to the front in a later state of progress. Thus from the point where symbols began to the point where these devices were consciously and customarily used it appears not possible to take up the subject of independent invention, not only from lack of data, but from the obstrusive question as to whether there were any data.

Considered as the simplest form, the straight line is usually given precedence, but apparently quite wrongly. A simple straight line connotes nothing. It is the zero of decorative art and as in the zero of mathematics was not discovered as a factor for ages. Thus the straight line in symbols of beginning decorative art is positional in relation to other straight lines, that is, two lines cutting each other, forming a diagonal or axial cross.

The development normally of decorative art seems to be with elements of the simplest form or *unit symbols;* intermediate forms or *combined symbols;* arriving finally at complex forms or *design.* As suggested, this evolution does not everywhere follow the normal course. Apparently from a given impetus the course of decorative design has been modified by racial or individual genius. Thus in one area there is a rapid development from a simple motive, and in another it is long and steady, from several incorporated motives gradually becoming wide-spread.

Viewed historically there is a constant flux between freedom and formality in art. It is customary to consider formality a decay from freedom, as a departure from an ideal. In particular this transfer has happened many times even in the most conservative periods among races, but must be regarded as sporadic, while the general course of the growth of the art instincts from the Stone Ages to the eras of achievement has been prevailingly from simple to complex. Thus the theory that decorative art begins with symbols and sculpture with the forms of surviving stone implements seems valid.

Use of Symbols

Property marks have received much attention as to their bearing on the origin of the alphabet. It is possible that these symbols entered into decorative art. Property marks are first noted as prevalent at the period of land- and sea-borne commerce, which began presumably in the Neolithic as an established social feature.

The theory is that traders adopted marks of their own invention for identifying such packages of goods as they ventured in the rude commerce of the times and that gradually these marks assumed a phonetic value furnishing the elements of an alphabet in a later period.

There is much to commend this theory, as it is logical to present a case for the marking of many kinds of personal property acquired during the increasing complexity of social life characterizing the Neolithic, Bronze and early Iron Ages.

Incidentally, evidence of this out-of-date illiteracy is seen far into modern times in the use by the folk of personal and family symbols and in the conventions of heraldry. A most illuminative example of the merging of symbols of various employment into decorative art is observed in Japan. Other countries present similar phases. An interesting legal survival is seen in the X which is "his mark."

There is abundant evidence of the practical and wide-spread use of symbols. It can not be proved that symbols are of any great antiquity; in fact, the weight of evidence is that they are the product of periods of pronounced culture advance. Nevertheless there is a feeling that these devices may have been used, though sporadically, in quite early times and some elements filtered down and were incorporated into the art of later times. Symbols, however, kept clear of art when used as economic factors—witness the English trade-marks sanctioned by Parliament 600 years ago.

While observations show that symmetry is at the basis of all art, it is rare that a purposeful analysis to determine a law of proportion has been experimentally worked out. The analytic mind of the ancient Greeks attacked this problem and was satisfied to accept the style which must have seemed bizarre at the time. Contrasted with primitive metrology, of which it was doubtless the resultant through a chain of fortunate circumstances, the Greek symmetry can only be regarded as a product of intellectualism too rarefied for continuance, but marking a climax of achievement.

Spread of Symbols

It has been customary to think somewhat loosely of symbols as a sort of currency which can be sequestrated, borrowed or dispersed through any of the happenings to races between peace and war. Really, the great bulk of symbols are closely bound to tribal art, being worked into design as part of decorative invention, and at least in the later stages rarely occurring in a free state connoting a single idea.

Some symbols considered primary seem also to have become widely diffused. One of these, the swastika, is wide-spread and has been thought to indicate racial connections over great areas. The swastika is in technique based on the unit axial equal-arm cross symbol and formed by the addition of short lines at right angles, the whole symbol intended to convey the idea of motion.

It would appear that the motion concept is the first composition factor to emerge in decorative art. It is seen in most compositions on the axial cross. A remarkable series is observed in ancient Pueblo pottery in which few four-part designs are balanced or static.

The wide diffusion of the axial cross makes it possible that from this symbol alone the swastika originated in many different art areas and this weakens the idea of diffusion by migration. The axial cross is important as a generalization obviously on position of the individual with respect to the external world which divides itself into quarters in accordance with celestial phenomena, that is, the rising and setting of the sun and the opposite points. In decorative de-

signs "here" is a round or square area from which the four radial lines project.

It is not necessary in some cases to begin with a formal symbol because as in the evolution of a Greek fret, from alligator designs of ancient Colombian art shown in the classic study of Chiriqui design by W. H. Holmes, both the square cross and the swastika are transmuted animal designs. In native design animal motives overwhelmingly predominate while floral motives are almost absent, being in the generality of observed cases the stigma of decay.

The circle is also a protean symbol to which various meanings have been assigned. Theoretically the circle originates from the square, and both may arise as a resultant of arrangement of design. The circle is wide-spread, but this is not evidence of cultural spread. The circle with a dot in the center may give evidence of transmission by borrowing in some cases.

The simple circle in design has often followed the use of the tubular drill, and it is also thought that shaped flints were used in the sense of a compass for evolving the figure.

Among the numerous free symbols that give evidence of the fertility of design among various races there are few known to have been borrowed in an extensive way. Mere contact of tribes appears to show borrowing, as the Navaho adoption of some Pueblo symbols, while the latter are coextensive with the pueblo region.

Mutations of Symbols

It is a common observation that there is a constant play of decorative fancy producing general and often profound changes in the units of design. In the life of a symbol changes occur, often rendering the basic symbol unintelligible, and sometimes after a long series of developments the initial form reappears.

Thus a design may begin with comparative realism, show a merging into geometrical or conventional, become entirely conventional and gradually play back again to the beginning with an entirely new meaning. There may be fragmentary remains of realistic in a conventional design, such as an eye or feathers, not erased by mutations and surviving as a clew to the surmised original motive. In these mutations geometrical breaks into curves, or oppositely, curves become geometrical, both sometimes occurring in the same decoration.

The question of primacy of realistic or geometrical is thus confused, the impression being that if realistic begins the cycle it is of very short duration. It is probable that under the designer's exigency the original breaks up into a number of parts or symbols, as the bird design of the ancient Pueblos or the animal designs of the Northwest Coast Indians so thoroughly studied by Boas.

It is probable that the theoretical realistic designs are generally absent and that the geometrics begin as lines with triangular or dentated margins, the lines used in combination parallel, converging or outlining wedge-shape spaces. These refer to free-hand work on surfaces as in pottery or skin painting. In basketry and other textiles the mechanical limitations force other treatment, but the mutations are quite as pronounced and varied.

It appears probable that early designs thought to arise out of religious concepts had a permanence not enjoyed by later designs of tribes in more advanced culture. This is in accord with the suggestion that tribes moving into a new environment tend to form new "schools" of decorative art. There are thus many beginnings, often with different origin impetus in motives as is the case with language. Language, as Herbert Spinden once said, is only an-

other form of art. Thirty-five hundred languages in process in the world would mean that speech is highly mutable and has little regard in formation to the time elements.

Instead of fixity the process of formation would be denoted as the play of language in which perhaps a few brighter individuals might, as arbiters of form, affect the course of style content profoundly.

In art such elements enter. The equivalent of language in the relation and relata of design, that is, the symbols and space components of decorative art, tend incessantly to mutations and even in time or certain circumstances decline and are lost perhaps to revive again. Sometimes the change takes place in the ancestral environment, for example, the loss of the Hopi ancient art pottery decoration and its recent revival noted by Dr. J. Walter Fewkes and the writer. Sometimes the art seems to originate from an introduced conception from a higher civilization, as the Vishnu standing between the horns of the water buffalo in Middle Celebes designs—apparently either not superimposed on native designs or eliminating them entirely. This phenomenon is so common that no other examples are needed.

The important cause of the mutation of symbols is primarily that no one can really copy, and for this reason the reproduction of a design leads to changes in position, line or form under the hand of the artist. Much of this is due to degrees of skill noted in the decorators in observed tribes. It is found that in a tribe of several hundred in which there is a general diffusion among workers of the practice of decorative art on pottery one excels, three produce work of class and fifteen or twenty rank low.

This spread is not observed so fully in basketry when the mechanical element is enforced by the routine of stitches, as stated.

Contents of Decorative Art

Evidently the contents of decorative art for a school or period must vary in amount, becoming richer as habitudes enlarge skill and extend the field. Evidently a school of decorative art may begin with a paucity of motives, in fact it is astonishing what an extensive flowering may proceed from a single motive. Notably, also, is this observed when there is what may be called a useful or economic need, as, for instance, in the decoration of bark cloth, for which there is a steady demand, or pottery, basketry, textiles and articles of skin.

A complexity of motives is not the rule in aboriginal decorative art. Here native designs are retained in purity, additions being evidence of racial dislocations and the inevitable processes mentioned. The contents of modern decorative art are clearly seen as an economic phase in which designs are adopted from any place and time, dissolving and reappearing like the patterns in the kaleidoscope. In this phase patterns have hopelessly lost their meaning, generally retained in aboriginal art.

In purer aboriginal art there is observed the use of a central motive lending itself to curved or formal configuration, together with relata of various sorts which set off or frame the prime symbol, affording the desired completeness or picturation of the design in a given area.

Surrounded by the relata the symbolic motive stands as a pure symbol in curved or geometric arrangement or modified to join with the relata. This is particularly observed in band patterns which seem to arise from the limitations or forcing of the design around the margin of the work, somewhat as the edgings of ancient Greek garments led to lace.

The relata or joining elements may be conjectured as arising in modifications of the lines which carry on the rhythmic

flow of the design through repetitions. There is a tendency of the symbolic motive to break up and mingle with the relata in such a way as to be difficult of identification. These structural lines may be bordered on one side with successive wedge-shape figures applied in a diagonal order or perhaps an earlier method by regular dentation. One side of the line generally is so treated. With these elements a remarkably complex series of designs may be elaborated. In some cases a design may be wholly of the serrated line arranged in geometric or diagonally arranged lines.

In general the pure line is sparingly employed and its use implies a considerable advance in art. Occasionally short lines of various lengths are used to produce a shadowy design or a mosaic effect. This procedure indicates a later and purer decoration.

There is also to be considered the breaking up of symbols into smaller units and the addition to symbols of modifying elements. The former is common in the substituting of a part for the whole or the expression of an idea conveyed by a part, the work being charged with decorative fancy actuated by whatever motives, religious or otherwise, may control. Especially is this seen in the anatomized bird designs on Sikyatki ware worked out by Dr. J. Walter Fewkes and in the Northwest Coast totemic designs by Dr. Boas. It is seen that this effort generally produces less effective designs than the older decoration handling fewer motives, such more or less discrete elements preventing the free flow of design.

Wherever data have been afforded for comparison it is found that in ruder decorative arts there is first the appreciation of a medium or surface, which is the background for design. This is a surface built as in pottery or to be built in process in textiles, or natural or slightly prepared as in bone, ivory or skin or the human integument. On any of these surfaces is placed a design standing alone with only a silhouetted relation to the background.

This design may be repeated in row order, but there is no interconnection of the designs and, therefore, no problems of the interplay of background spaces and pattern figures. These relations are to be gradually appreciated and worked out in the course of the development of decorative art.

Examination of various grades of efforts shows that the problem of spacial application of designs with relation to the background makes for good or bad design.

Also repetitive motives in apposition almost enforce modification of the surface areas of patterns. Thus by hatching or lining parts of patterns variety is secured, and the designs seem to show the idea of duality as in Pueblo pottery.

Harmony of design and background is an evidence of advanced decoration. Sometimes indeed it is difficult to disengage the pattern and background and determine which is the pattern indicated by the artist. Complex patterns in higher decorative art sometimes show the genius of the decorator in the composition of a design in which beauty, harmony and intricacy are combined. Sometimes also the product may be compared to a problem in higher mathematics.

Some designs are repetitive and have little meaning except their general religious intent, as in band decorations or borders.

Often the designer breaks away from the customary usage and produces a free decoration. This is observed especially in the pottery of the Little Colorado Valley where everything was tried out. This is evidence of a later development when the decorators were freed from the trammels of the older black and white pottery motives.

Conclusions

Art, like language, has apparently no prime point of origin or continuity of development. They seem, together with other esthetic and intellectual classes, to be of sporadic growth. The line of development which can be drawn in material culture is not so evident in the intellectual complex. Nevertheless some law, as of population pressure, may fertilize and bring to fruition the elements of this complex, on the whole showing an advance.

Thus we must consider that, as in development, races never arrive at the same place, there are no comparable stages in art. Environment and other obscure causes do, it is affirmed, enforce similarity in gross.

It would seem that in the human texture, called culture, we must recognize that, as in the physical world, mass action represents behavior rather than the results of the movement of small units which lead us astray as to the general or average trend. In this sense it is necessary to avoid basing the origin and development of art on local phases, and we must instead vision the growth of art on broad and comprehensive lines.

CIVILIZATION AND THE MIXTURE OF RACES

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WHEREVER the members of divergent racial stocks have come into contact they have associated to produce a group of nondescript hybrid offspring. The social and cultural status of these half-caste individuals is determined by the attitudes of the politically and culturally dominant group. They may be accepted as a lower stratum of the dominant culture group; they may be classed as members of the exploited group, or they may be formed into an intermediate class or caste. For a longer or shorter time the two racial groups may live side by side, in a state of relative separateness, each maintaining a semblance of racial and cultural integrity. But the hybrid population grows by natural increase, by the continued intermixture of the races and by the intermixture of the hybrids with each of the racially separate groups. The uniform results are an increase of the hybrids at the expense of each parent group, the present disappearance of racial lines and the ultimate mongrelization of the entire population.

At the present time the contact of racial stocks is incomparably greater than at any previous time in world history. The rise of modern science laid the basis for a new world order. It made possible a machine industry with an enormously increased production of material goods at the same time that it brought new types of communication and cheap and rapid means of transportation; it made possible and inevitable a world-wide commercial and economic unity that brought into contact and association peoples heretofore widely apart. But it brought also a spread and deepening of popular education with a consequent growth in objectivity and a weakening of sentimental and traditional controls; it operated directly and indirectly to the economic and intellectual liberation and mobility of the individual man. The new freedom, in the presence of the marked differential in economic opportunity in different regions, got expression in an unprecedented migration. This led to the contact and intermixture of diverse stocks previously widely separated, to the exclusion and absorption of weaker peoples and to the repopulation of whole continents by the amalgamated stocks.

This wholesale and indiscriminate intermixture of biological strains is, in extent at least, unlike anything before known in the contact of peoples. The conditions of the miscegenation have in many cases violated conventional and formal standards and expressed, or given rise to, serious social disorganization and personal demoralization. The facts as well as the apparent immediate consequences have aroused active and violent emotional condemnation. The general public as well as many social students impute great significance to this amalgamation of the races. The prevailing note in the sociopolitical discussion is one of pessimism: there is fear of racial degeneracy, moral decadence and culture decline; an uneasy and unanalyzed sense of impending racial and cultural disaster. In some cases this emotional attitude has been expressed in formal and legal as well as in popular efforts to check the movement already accomplished or beyond control.

It appears to be fairly well established

as a biological fact that neither inbreeding nor outbreeding has any beneficial or injurious consequences. The experimental manipulation of both plant and animal forms seems to have demonstrated that sound stock may be inbred indefinitely without ill effects and that no ill effects follow from cross-breeding. The characters that appear in the offspring are determined by the presence of genetic factors which come from the immediate parents of the individual form. The hereditary traits that mark the ancestral lines appear in the offspring in definite and predictable ratios quite independent of whether the parents are of the same or of different racial strains. Inbreeding makes more likely the appearance of recessive traits, while cross-breeding decreases the likelihood that such traits will appear. But this is simply a question of the presence or absence of similar heritable traits in the parents and not at all a question of in- or cross-breeding. Neither inbreeding nor cross-breeding can produce any characters not latent in the ancestral strains. On the basis of the biological facts and evidence there is no reason to anticipate anything noteworthy as a result of the crossing of human stocks; it would appear to be a matter of relative indifference. But as a matter of historic fact the crossing of racial strains often has been associated with cultural phenomena of utmost human significance. The amalgamation of divergent racial strains seems always to be accompanied or followed by more or less profound changes in culture and social organization. The facts have attracted much attention and have been variously interpreted, but the actual relation, if any, between the biological fact of race crossing and the efflorescence or decline in culture is not generally understood. Two opposing doctrines have held the field.

One school has occupied the position that racial stocks are somewhat grossly unequal in degree of native capacity for cultural achievement. They stand to each other in some sort of mental hierarchy. The existence of a superior racial group is a precondition to the appearance or even to the use and maintenance of complex forms of culture and social organization. Creative men can be produced only by a superior race. On the basis of this major premise, the argument runs to the effect that any intermixture of the unequally endowed stocks raises the capacity of one at the same time that it lowers that of the other. The net result of amalgamation is a decadence in racial stock and a corresponding decline in culture status.

The argument in support of this position takes numerous forms—biological, psychological and historical. In detail it is frequently highly complicated and, in the hands of different men and sometimes in the treatment by one man, the most contradictory data are marshaled in its support. The major part of the discussion has concerned itself with an effort to demonstrate the unequal endowment of racial groups. This is central to the whole doctrine. If it be established, the intermediate culture capacity of the mixed group and the mixed-blood elements of composite groups would seem to follow as a matter of course. If, however, this is not established, it is difficult to see that racial crossing is a matter of any racial consequence. So, whether as an initial assumption or as a final conclusion, the effort of the school is to show that culture is a function of a particular racial group. In its Western form, to which attention is here limited, the effort is commonly made to demonstrate that civilization is a possibility for the white race only or even for only some one branch of the larger division.

A demonstration of the superiority of the white racial stock has been often attempted on purely physical grounds.

If the racial groups differ in their degree of resemblance to the simian forms it may be possible to show that they represent stages in evolutionary development. In certain respects the whites are more sharply in contrast to the apes than are other races. This is notably true with respect to brain weight and size, in which respects they overtop the other racial divisions. Assuming a correlation between the size of the organ and the efficiency of its functioning, the inference is immediate: the white racial groups excel the colored races and the north European white stock is superior to the other subgroups of the white division. The supporters of this doctrine commonly extend its scope to include sex and class differences within the given society: women are inferior to men in size of brain and hence in the efficiency of their mental processes; the aristocratic, leisure, educated, professional and other well-fed groups excel the socially inferior groups in the average size and weight of brain. The greater historic achievement of the upper classes and of men over women is taken as a cultural expression of the biological facts.

The Spencerian position just outlined has been supplemented and refined by certain findings of experimental psychology. Recently many different tests have been constructed in the effort to measure the comparative mental ability of individuals. They are designed to separate native equipment from cultural acquisition and measure the former apart from the conditioning effects of the latter. Experimentation along this line has led to the general conclusion that white children are superior in native capacity to children of other racial groups and that the degree of superiority varies from one subracial group to another. There is also said to exist a positive correlation between social status and native capacity. To be sure, there is no complete agreement even among the testers themselves, and there has been much unanswered criticism of the technique and of the findings based thereon. But the conclusions from the use of this recent device of the laboratory are in substantial agreement with the conclusions of the Spencerian argument.

Various writers, approaching the problem from the point of view of the historical evidence, support the same thesis. They find that the great civilizations of the world have been the achievements of the white race or of the white elements of the populations. "Everything great, noble and fruitful in the works of man on this earth, in science, art and civilization, derives from a single starting point; it belongs to one family alone, the different branches of which have reigned in all the civilized countries of the universe." The Indian civilization was the work of this gifted group, while the Egyptian and Chinese civilizations began with colonies from India. The ancient Greeks and Romans, in the period of their glory, were more Nordic—"Aryan"—than the present-day Greeks and Italians, and it was these superior elements that brought about the efflorescence of classic culture. The modern civilization is said to be the unique product of the Germanic races. "It is a definite species of mankind which constitutes the physical and moral basis of our north-European culture." The modern nations—England, France, Germany, the United States—are expressions of this racial genius; civilization without an Aryan creator is impossible. Often it is claimed that only the Nordic elements of this racial division are of cultural worth: "The less Teutonic a land is the less civilized it is." In those cases where some degree of modern culture has appeared among the non-white races, the phenomenon is understood as a copying of Western methods: it is an imitation rather than a spontaneous native growth

and would go into rapid decline but for the stimulus and model of the really superior groups. But some groups are said to lack even an ability to copy. One modern writer, speaking of the Negroes, insists that they lack the capacity even to comprehend many of the elements of white culture and can of course add nothing to it, though they may be able to use some parts of it.

If racial groups are widely divergent in mental ability and culture capacity it follows immediately on logical grounds that racial injury and culture disaster must follow their miscegenation. A large body of historical data has been marshaled in support of the position. Just as the flowering of the culture peoples was a function of a superior racial stock, so their decadence followed up their miscegenation and the dilution or extinction of the white racial elements. The racial intermixture with the Negroes, brought into the Egyptian population as servile laborers, marked the beginning of the end of a great people. The mongrelized descendants were unable to advance or even to maintain the culture status, and Egypt disappeared from the family of culture nations. Greek immigration, resulting in intermixture with inferior and servile groups and the sterility of superior family lines, increased the relative numbers and dominance of the hybrid and inferior strains and so brought racial and cultural decline. Rome is a repetition of the story of Egypt and of Greece. The original stock was corrupted by racial intermixture, and the mongrelized group lacked the capacity to perpetuate the culture. The brilliant culture of the Renaissance was followed by an era of chaos because the "caste lines protecting the Teutonic aristocracy from blood contamination were broken down."

The cultural distribution of the modern world is made to tell the same story. The mixed nations are the backward ones. The Mexican population is a hybridized Indian group, superior to the native Indian, perhaps, but inferior to the Spanish that mingled its blood with that of the native women. South America, generally, shows the cultural consequences of miscegenation with a physically divergent and culturally lower group. In the United States the native Indians were destroyed and the country repopulated by a north European stock; in South America the races interbred. The present cultural contrast between the North and the South American countries is cited as a consequence of this difference in racial policy and practice. French Canada is another case in point: the numerous cross-bred French-Indian population is superior to the native Indian, but so sadly below the intellectual level of the French that they are unable either to preserve the French culture or to assimilate that of other peoples. Numerous other groups illustrate the result of racial crossing: hybrid groups are everywhere backward and decadent.

To persons untrained in the rigorous logical processes of scientific thought and with only a superficial acquaintance with the body of historic reality the position seems convincing. It is simple, direct and in line with the spontaneous prejudices. Many writers, striving for popularity, have exploited the doctrine to an uninformed and eager audience. There has grown up a considerable body of pseudoscientific literature that stimulates at the same time that it caters to the popular beliefs and prejudices.

A second, opposing, doctrine emphasizes the importance and the cultural desirability of racial amalgamation. It is frequently little more than an attempt to refute the position just outlined; the affirmative doctrine, as often as not, goes by implication rather than by direct exposition. The school recognizes the fact that racial intermixture results wherever divergent groups come into association. But the contamination of a stock by the

incorporation into it of other stocks is looked upon as an occurrence that heightens racial capacity and culture worth. The hybrid offspring are likely to be, or demonstrably are, superior to one or both parent stocks. Racial crossing foretells an improved race and culture. The earlier mixture of stocks explains the present cultural status, and the present-day mixture is a basis for anticipating still greater culture achievements.

Every great people, it is claimed, rests upon a mixed racial base. Whenever in the history of culture there has been great achievement it has been the expression of a hybrid rather than of a pure racial stock. "All historical nations have been of mixed blood." "The rise of culture in Greece and Rome, as indeed in western Europe, was in every case preceded some centuries by the conquest of one racial type by another and their subsequent amalgamation." The achievements of the modern world are the cultural expression of hybrid stocks. England, Germany, the United States—the population of every modern nation—is a composite of imperfectly blended stocks. The culture achievement is a function of this fact. Effort is also made to show that many or all great men are of mixed racial stocks.

The general position is supported by evidence drawn directly from the character and status of mixed-blood individuals and groups in the present-day world. Where two divergent groups associate to the production of an intermediate type, the achievement of the hybrid individuals as well as the cultural status of the mixed-blood group as a whole is superior to one, at least, of the ancestral types. Cases are cited from every area of miscegenation. The mulattoes resulting from the association of Negroes and whites in the United States are superior in status and accomplishment to the unmixed Negro group, and individuals are often well above the average of both the ancestral groups. With few exceptions every American Negro who has risen above mediocrity has been of mixed racial parentage. A somewhat similar condition appears to exist in other similar areas. The Negro hybrids of South Africa, the West Indies, Brazil and elsewhere are, on the average, culturally above the native elements of their ancestry. In some cases these hybrid groups have produced men of real caliber. In nearly every case, the American Indians who have participated in the European culture have been men of mixed ancestry; apparently no American Indian of full blood has risen above mediocrity in, and measured by, the culture standards of the dominant group. The French-Indian hybrids of Canada are individually and as a group above the culture level of the Indian ancestry. The *mestizos* of Mexico and Latin America, the hybrid Eskimos, the Hawaiian and Philippine mixtures and numerous other minor groups of hybridized stock are in culture and social status above the level of one at least of the racial ancestors.

The same general position is supported by a body of negative evidence. The population groups in the modern world with the highest approximation to racial purity are just those groups of most meager cultural accomplishment. The fragments of primitive groups still living are the purest in blood and the lowest in culture of existing populations. In America the white stock with the lowest index of recent racial intermixture are the southern mountaineers. They are at the same time the most culturally retarded white group in the American population.

On the basis of such selected cases it is possible to maintain with some show of evidence the position that culture is dependent upon the intermixture rather than upon the purity of racial stocks.

The two positions stand in more or less direct opposition: one doctrine holds that civilization is an expression of racial purity, or at least can arise only in the presence of a great race of purity, and that culture declines with the decadence of racial stock that results from the intermixture of races; the other asserts that civilization is a result of the mixture of races, that the amalgamation leads to racial virility and cultural efflorescence and that purity and inbreeding of stock lead to racial degeneration and to the decadence and sterility of culture.

Such conflict of doctrine must have a basis in something more fundamental than a simple difference in the reading of the facts; confusion of thought is not persistent in the presence of examined assumptions and rigid definitions. It is desirable, therefore, to turn from the positions occupied to the major logical presupposition upon which they are both erected.

This presupposition, sometimes definitely recognized and stated, sometimes unrecognized and naively assumed, is that culture is a function of race and grows and declines with changes in the composition of the racial stock.

The position of the racial purists, as that of their opponents, rests upon the assumption that a causal relation obtains between race and civilization. Both give a racial interpretation to institutional growth. Civilization is assumed to be a function of race, an expression of racial qualities. Whether the position occupied be that culture efflorescence is a result of racial purity or that of hybridization, or that culture decline is a result of miscegenation or of inbreeding, the basic assumption is that the culture facts are in some direct way determined by the fact of biology. The tenability of either position, therefore, turns upon the soundness of this assumption. It must be shown that culture is a function of race, else it can not be admitted that the degree of purity or mixture of racial stock is even pertinent to the discussion.

The origin and persistence of this assumption is interesting and enlightening. It arose and prevailed because it offered an explanation within the comprehension of the simple mind. The spontaneous tendency of the popular mind is to assume a direct cause and effect relation between coincident phenomena and between phenomena that stand to each other in temporal sequence. It is a matter of proverbial wisdom that the naive person transfers his emotional reaction from a bit of unwelcome news to the carrier of the information. The whole body of folk superstition is an exemplification of the same type of logical error. Where a direct causal relation actually obtains between coincident phenomena it is not unusual to find misapprehension or even complete reversal of the determining rôle of the coexisting factors: which is taken as cause and which as effect is determined in many cases by the individual or social bias of the observer.

This tendency to assume causality because of coexistence or sequence is particularly pronounced in questions of a biosocial nature. The relation of social and biological facts and processes in the universe of reality is not generally understood. The facts of human culture do not appear or persist apart from the facts of human biology; there are no human beings without culture; there is no culture without human beings. Moreover, the differences between the various racial groups and the various culture complexes are gross and notorious. A similar relation has existed throughout the historic era. It is perhaps inevitable that common sense should draw the inference that the culture complex is a function of the racial variant with which it is associated. The

observation of gross physical differences leads to the position that there are corresponding mental differences which, in turn, are assumed to account for the variations in culture. The prominence of the European Jew in financial circles leads to the position that the group is somehow peculiarly endowed for commercial venturing. The poverty and ignorance of the Negro are commonly accounted for in terms of a native mental incapacity consequent upon the factor of race. The more culturally aggressive peoples of the day are of north European origin; the inference is easy and direct that their cultural status is an expression and a consequence of the racial factor.

This type of common-sense explanation arises spontaneously in the presence of any group of phenomena in spacial proximity or temporal sequence. In biosocial phenomena it tends to persist partly because its flattering implications do not offend the dominant races and classes and are not so subtle as to escape their attention. Moreover, the doctrine puts the ineffective classes and retarded races somewhere outside the strictly human groups to which the ethical imperative applies and so affords a basis and justification for the urge to use and exploit them.

But the assumption persists in part for the reason that the objective relation of the biological and cultural facts has not been adequately emphasized. It is difficult to find anywhere in the literature of biosocial reality a clear analytic statement of the interdependent relationship of organic and social reality. The spontaneous common-sense views, as well as the rationalizations in justification of colonial and other types of exploitative policy, are able to persist because of this absence of a definitive analysis of the relationship of the fundamental processes.

Race, whether the word be used to designate a biological entity or merely a relative biological stability subsequent to intermixture, is a product of inbreeding. The heritable divergences arising in any stock become established as racial marks in the degree to which the individuals bearing the marks are structurally or otherwise isolated. In the breeding of plants and animals to the establishment of a new line, or to the maintenance of a thoroughbred stock, individuals showing the desired characters are separated from others and inbred in order that the traits may be fixed and characterize the strain. Without such separation there is cross-breeding, mixture of characters, the production of hybrid offspring. Exactly the same thing is true of human forms. Purity of race is a result of variation followed by long periods of isolation and close inbreeding of the variant forms. The heritable racial marks are fixed by inbreeding; they are lost in cross-breeding. Without a long period of isolation, whether it be maintained by spacial separation or by conventional barriers, distinctive racial marks are lost and purity of race is non-existent. The only human groups of even relative racial purity are those that have been separated from foreign contacts and inbred through long periods of time. Some of the Eskimos, the American Indians of the Southwest deserts, the interior tribes of Australia, the Andaman Islanders, the hill folk of India, are among the human groups that most nearly approximate purity of racial stock. Their purity is the result of their isolation.

Cultural development, on the other hand, is a consequence of social contacts. Isolation results in cultural uniformity; in stability and fixity of standards; in a régime of suppression, of law and order; in traditional behavior and cultural stagnation. Social

contact means the introduction of new values and methods and divergent ideas. The new may come of course through independent invention and discovery which disturb traditional practices and beliefs and initiate social change. But in general the contact of peoples is a precondition to culture growth. Historically, every civilization has followed upon a period of migration. Every European culture followed upon the contact of different tribal stocks and cultures. The contacts resulted in the introduction of divergent standards and practices and in the breakdown of cultural equilibrium. All progress is made in periods of disorder when individuals are freed because the formal controls are ineffective and the primary controls are conflicting. And change, by contributing to the disorder, is itself a factor in further change.

The two processes thus stand in fairly definite and sharp contrast. Isolation is an essential precondition to racial purity. But the uniform and inevitable effect of isolation is cultural stagnation and retardation. The people most pure in race are most retarded in culture. Contact, on the other hand, is a condition essential to culture growth. It brings the divergent standards, the strange beliefs, the new practices and the fruitful ideas and methods which disorganize the established order and free the individual. On the biological side, the uniform effect of the contact of races is a mixture of blood and the ultimate production of a modified racial type. But the biological intermixture is aside from the cultural development: both result from the contact of peoples but neither is a direct cause of the other.

The assumption common to both parties to the controversy over the effect of racial amalgamation on civilization is that culture is somehow a function of race. When it is recognized that this position is untenable, that races and culture are independent facts and processes, the whole controversy is without point. Either purity of race or mixture of race may go with either a superior or a retarded culture. Neither racial amalgamation nor racial purity is a causal factor in civilization; neither offers any explanation of cultural decadence.

It is, however, an extreme position to assert that racial amalgamation has no cultural significance. In an indirect way the crossing of races is conducive to social change. In its earlier stages, at least, the intermixture of races takes place for the most part on the outskirts of the civilization. It is in general contrary to the tradition and in violation of the mores; it is usually extra-matrimonial and shocking to the conventional moral standards; it is condemned, opposed, forbidden. Racial miscegenation in these early stages is an evidence and form of social disorganization. It contributes to social disorder, disintegration and confusion of standards at the same time that it makes them evident. It is of course from social disorganization that progress must proceed: change is not possible without it. On the other hand, the social disorder incident to the contact of variant standards and practices is conducive to the violation of the traditional sex tabus, hence is favorable to racial miscegenation.

FIRE, A PROBLEM IN AMERICAN FORESTRY

By E. I. KOTOK

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An annual crop of 158,000 forest fires in the United States explains why American foresters devote much of their time and effort to the problem of fire control.

Forest fires, although they have increased in number and severity within the past half-century, are not a recent phenomenon in American forests. They were prevalent through the centuries now past, as a result of both natural and artificial causes. Within historic times we find the earliest European travelers in America speaking of sweeping holocausts that scourged the forests, blackened the skies and drove game animals before them. These reports are not restricted to one locality; they are mentioned in accounts from Maine to Florida, and from the Atlantic to the Pacific. The observations of European botanists who visited this continent in the early days of its history contain some very keen comments on the effects of fires on the flora and forests. Even Dana, in his "Two Years Before the Mast," vividly describes a raging forest fire on the mountain sides near the present site of Santa Barbara (1840). Mark Twain in his own impish way recounts his setting fires in the Lake Tahoe region just to enjoy the spectacle.

But we need not rely on such historic and literary evidence to know that forest fires were common in American forests. The forests themselves offer the best evidence of what has taken place. For example, the fire history in the California pine region has been partially reconstructed from the evidence of fire scars left during past centuries on thousands of trees. Fortunately, in the process of healing, each fire wound has been carefully covered by a layer of woody growth, thus preserving the scar as a permanent and indelible record of a fire that once covered a given area. Even after the lapse of centuries it is possible to count back the number of annual rings overlying the scar, and to determine the exact year of injury. Boyce, in his study of "Dry Rot in Incense Cedar," which required cutting down in sections thousands of trees, furnished the most complete record bearing on fire scars in the California pine region. This study extended from the Oregon line, through the Sierras, to the southernmost part of the California pine region, and this territorial cross-section gives an adequate basis for drawing a picture of the fire history for a large region. We find in this material that the earliest fire recorded was in 1530. From about 1700 the frequency of scars increases, and the fire history can be more precisely followed.

So it is found that there have been bad fire years in which fires covered practically the entire area of the pine region. At an average interval of eight years and dating back at least to the end of the seventeenth century, fires ran through the timber, leaving their mark, just as fires do to-day. The years 1685, 1690, 1699, 1702, 1708, 1719, 1726, 1735, 1743, 1747, 1757, 1759, 1766, 1786, 1796, 1804, 1809, 1815, 1822, 1829, 1837, 1843, 1851, 1856, 1865, 1870, 1879 and 1889 were bad fire years, as indicated by thousands of scarred trees throughout the mountains. The shortest period between fires is three years, and the longest eleven for the pine region as a whole.

Huntington's investigations of the *Sequoia washingtoniana* enables us to carry the fire history as far back as A. D. 245.

The query arises, if fires have always

prevailed in the forest and nature has been able to adjust itself in their reestablishment, why do foresters place such emphasis on the importance of complete fire exclusion in American forests? The answer, of course, lies in the fact that the forester is concerned in producing and maintaining maximum values in the forest. Fire is not compatible with this objective. Evidence everywhere indicates that even in the finest virgin forests we do not find anywhere near the volume of cellulose which forest lands under complete fire exclusion can produce. For example, on the best sites in the California pine region, areas carrying an average of 35,000 board feet of timber per acre are considered exceedingly dense and productive forests. These virgin forests represent an average age in standing timber of 200 years. In contrast to this value, we find on 60-year old second growth stands in the same region, where fire has been completely excluded, a production of 80,000 board feet of timber per acre.

The virgin forest as the white man found it was the product of soil and climate in which fire was an important modifying agent. In some regions fire was the major dynamic force which moulded and shaped the character of the forest. Whereas endemic infestations by insects or parasites always affect most seriously the older tree age classes and forward the processes of decomposition of single species, fire takes its toll from all age groups and all species simultaneously, even including the destruction of soil.

Fire in the virgin forests acts destructively in many ways: 1. By burning down previously fire-scarred trees by the process of undercutting the base of the tree so that it can not withstand the mechanical strain placed upon it.

2. By heat-killing, causing either complete destruction of foliage or, more often, the killing of the cambium layer.

3. By burning part of the crown and reducing the vigor and rate of growth of individual trees.

4. By reducing of vigor, increasing susceptibility to insect attack, and through scars offering opportunities for infections by fungi.

5. By completely wiping out younger stands of trees in the seedling and sapling stage which should form the subsequent crop after the cutting of the mature stands.

6. By reduction of the site quality through the removal of organic material and accelerating the process of erosion.

Even the lightest fire may produce some of these deleterious results. In intense fires, under adverse climatic conditions of high wind and low humidity, or where fuel content has been increased through slashing of the forest, complete destruction over large areas may be expected.

In the wake of each fire nature at once begins its processes of restoration through a series of ecological successions. In these successions the more fire-resistant arborescent species and frequently the least desirable replace the more valuable commercial species. There are, however, many exceptions to this rule, where the climax types have been wiped out and the temporary types include very valuable commercial species. In all these processes nature takes abundant time. The forester, however, is confronted with the alternate problem of maintaining continuous forest values within reasonable time limits. Fire introduces a factor of delay and uncertainty.

So far, we have discussed the problem from the standpoint of cellulose production and the effect of fires on this production. Forests have, however, other important values which are seriously impaired by fire. In the western United States, where forests have peculiarly significant bearing on water resources, a single fire, by the removal of the vegetative cover, may produce disastrous re-

sults to dependent agricultural lands. Our experimental data show that by removing through fire the litter, humus and organic material in the forest there will be an increase of immediate run-off one hundred fold, and of eroded material one thousand fold. Where a forest becomes an important watershed it is obvious that every fire is a threat to dependent agricultural land areas. Time here is again an element of importance. Fires in the past affected the water cycle just as they still do, but nature had unlimited time in which to readjust a balance.

It is safe to say that there are no forest regions in the United States, particularly in the commercial tree belts, that are free from evidence of past fires. From this it does not follow that fires have affected the forest adversely to the same degree in every region. In a recent preliminary study in which an effort was made to determine the relative protective needs against fire for the various regional national forests, an interesting relative scale was evolved indicative of damage to forest values for the important forest types of the United States. While this scale is based on the most accurate information of damage studies available, it can be accepted only as a tentative guide pending the accumulation of more accurate data from far more intensive studies. In determining the degree of damage that follows fire, these factors were considered: the extent to which tangible forest values were destroyed; the degree in which the productive capacity of the forest was reduced; the probability of reestablishment of the forest within a reasonable period.

Part of this tentative scale is included here merely to illustrate how variable the effects of fire may be for different forest types, and also how important the forest type itself may be in considering the fire problem for a given region. The spread in damage between forest types is considerable, being heaviest in the types with the deepest duff layers and in the more uniform age groups.

The relative damage may be expressed as follows (unity represents highest damage): Spruce, 1.0; White pine, 1.0; Douglas fir, 1.5; Western yellow pine, 2.0 to 4.0; Northern hardwoods, 1.5; Appalachian hardwoods, 5.0; Longleaf pine, 15.0; Sand pine, 10.0; Loblolly pine, 7.0; Shortleaf pine, 7.0; Lodgepole pine, 5.0 to 8.0.

The degree of damage that may follow a fire in a given type is highest in some of our valuable forests, as, for example, the spruce, white pine and Douglas fir.

The forester's interest in fire lies first in the fact that his crops, forage or timber, ready for harvest, are threatened; that his lands may lose in productivity, and these losses impair the value of his property immediately. The forester must have an accurate knowledge of fire to understand fully how it has moulded and shaped the forest as he finds it. On this knowledge can be founded a sounder silviculture, and methods for combating successfully and systematically future threats from fire.

With increased use of the forested areas of this country, and with the development that has followed, forest fires have been generally accepted as a necessary evil. Whole-hearted public support in the prevention of fires, in spite of all the evidence of their destructiveness to our forest resources, has not yet been attained. Strange as it may seem, we still hear men of science offer arguments in our western United States in support of "Indian forestry" and the light burning of our forests—a theory and a practice evolved by selfish interests, misguided into the belief that forest fires bring forth luscious forage, bountiful game and open, park-like forests. Until the forester is able to secure reasonable fire exclusion, the development and use of our western forests will be delayed for untold centuries.

A THIRD ALTERNATIVE: EMERGENT EVOLUTION

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THE doctrine of *vitalism*, which holds that life has its origin and support in some principle that is neither material nor organic, has long been subrosa, timorously or frankly discounted by many people. Certainly, the preponderant opinion among scientists is one of agnosticism, skepticism or outright doubt of the existence of a vital principle, entelechy, psychoid, or any kind of immaterial, initiating force or vitalistic entity as ruling, in any sense, the origin, reproduction, growth and activities of plants, animals and man. This tide of disbelief in the supernatural appears to be rising rapidly, and it is hardly more buoyant without than within the churches; for the more liberal ministers and members seem to be coming to regard the supposition of vitalism, especially in its more flagrantly augural and magical forms, as inconsistent, incoherent and bankrupt.

As dissatisfaction with the vitalistic conception, in its various forms, has grown, many experimenters and leaders of thought have resorted to the exploration and exploitation of the doctrine of *mechanism*, as apprehended by most physicists and chemists and many biologists. According to the mechanists, every event should be computable and predicable; all the parts, arrangements and motions which compose and contribute to the operations of the universe follow the same laws at all times; what appears to be new or mysterious is so only to the extent, and because of its not having been previously, or yet discovered and reported; no new principles or methods of action are ever involved, and the mind or mental state does not have command over contingencies to any extent whatsoever.

The present exalted position of mechanism has been merited through a procession of discoveries and facts. To whatever extent phenomena have been elucidated, all have been found finally to rest exclusively on materialistic bases. We are still awaiting the results of a single, controlled experiment, or observation, which exhibits facts to the contrary. To cite the vast part of the cosmology which has not yet been explained physicochemically renders these mechanistic prognostics none the less exclusive and indicative. Some of the accomplishments, in broad outline, have been the magnificent results in mathematics and astronomy by means of which, among others, celestial phenomena may be predicted with practically perfect accuracy, courses charted and schedules of tides made out long in advance, and intricate as well as monumental structures planned and erected. Developments in biochemistry and physics, physiology, pathology, endocrinology and genetics, as well as other lines, which are rendering incalculable service to mankind, have undoubtedly been promoted by the discard, at least in practice, of the idea of the potency of the vitalistic supernatural.

The discovery and application of the Mendelian laws of heredity, the coincidence of these laws with the behavior of the discrete bodies, chromosomes, in the nuclei of the cells, and the development of T. H. Morgan's workable linear hypothesis which allocates within the chromosomes the factors responsible for the characteristics of plants, animals and

man have all been apparently in line with the tenets of mechanism. Bateson has also quickened the imagination of the mechanistically inclined by the suggestion of the analogy of the breeding cages and pens of the geneticist as instruments comparable with the test-tubes and mortars of the chemist, and the behavior of the genes (hereditary factors) as resembling the chemical elements in analyses and syntheses. Studies in human heredity, as initiated by Galton and carried forward by Davenport, Laughlin and others, have revealed that such discrete characteristics of man as are available for study, and there is now a long and imposing list, follow definite and predicable rules with as much regularity and accuracy as are inherent in other features of science.

Thus it has come to appear that biological phenomena, until recently regarded as in the hands of a fickle god of chance, or directed by categories of capricious entelechies, might be subject to a considerable degree of quantitative predication. The prodigious array of impressive achievements, hardly begun to be described here, has gone far to increase the conviction that the mechanistic conception, hitherto mainly reserved and restricted to the physical sciences, would also serve to explain vital phenomena.

That extraordinarily beneficent and manifold improvements in the material welfare of mankind have accrued from this swinging of the pendulum from the régime of whimsical, inconsistent and depleted vitalism can not be gainsaid, and on this account the movement is not to be deplored. However, from the standpoint of free-will, or optimistic self-determinism, the materialistic assumption appears to many as contributory to pessimism, and highly subversive of the hopeful and purposeful initiative which to this time has been regarded as one of man's most salutary, differentiating and conspicuous attributes.

The third alternative is the doctrine of emergent evolution, so-named, but not first suggested, by C. L. Morgan, and supported by Alexander, Spaulding, Sellars, Smuts and others, some of whom have given the hypothesis the descriptive terms "creative synthesis," "organicism," "holism," etc. This doctrine assumes that examples of emergence, the incoming of the new, beyond the computable, additive or resultant expectations, though still subject to the peculiarities of the components, are to be observed in practically every feature of the universe, as water from the synthesis of hydrogen and oxygen, common salt from chlorine and sodium, gunpowder from the mixture of sulphur, charcoal and saltpeter, words from the letters of the alphabet, green from uniting yellow and blue and the chord from the combination of musical tones. In the whole web of substances and episodes from atom to solar system, from monera to man, and from antdom to kingdom, in all the implications of the latter word, there is ever and inevitably this incoming of the new which, though depending on the characteristics of the constituents, is incomputable, more or less, than, beyond or below, and never the same in all respects as the accretive resultance of the several component elements.

As in the examples suggested, every discrete feature of living as well as nonliving substance may be regarded as superadvenient over, or extraneous to, the mere sums, mosaics or additive resultants of their respective, constitutive parts. The laws relating to and governing the whole are also comparably as restricted and peculiar to it as the laws attributive to and controlling the several constituents are exclusive and limited to them, and those of the one may not be even adumbrative of the others. What could be more surprising than that such a novel substance as water should be the outcome, not the mere sum, of the uniting in a certain way of two such

gases as hydrogen and oxygen? What an emergence of new properties! If just one more element, carbon, be utilized what an array of emergent substances and forces may the chemist produce for us, including ether, if these elements be combined in the one way, or ethyl alcohol when there is another arrangement of them. If we were not so commonly familiar with the preparation and use of such compounds, so dissimilar are they from, and so completely do their various properties dissimulate those of, their respective component elements, it would be difficult to believe our senses at a first experience with their production.

In order usefully to conceive of emergence, stress must be placed on the incoming of the new, the *supervenient properties* of the various products of combinations and syntheses of atoms, molecules, crystals, protoplasmic cells, organs, hereditary characteristics, color patterns, individual organisms into societies, and functions of cells, organs, individuals and subgroups. Thus they are more than the sums of the attributes of atoms, though still consequent upon their peculiar functions, that characterize the various molecules they make; a protoplasmic cell (example, ameba) exhibits properties that utterly adumbrate those of its constitutive molecules (does water any less?); the mule is more vigorous, and, in most respects, superveniently different from the mere accretion, or mosaic, of the several qualities of the ass and horse parents, and the catalo is far from displaying nothing but an addition or mosaic of the respective characteristics of cattle and buffalo. It might be challenged if there is any object or substance, beyond the protons and electrons, non-living or living, from atom to galaxy, which is not actually an advent of the emergent new. All the pages of this journal for a period of years might be devoted to a still incomplete list; "it is beyond the wit of man to number the instances of emergence."

I have, elsewhere (*Science,* April 11, 1930), lately undertaken to indicate the apparently pertinent coincidence between the supposition of emergent evolution and the more recent apprehension of hybridism. Plant and animal husbandmen have, from time immemorial, noted that the hybrid product from the crossbreeding of individuals of different, somewhat distantly related strains, varieties or even interfertile species was likely to be widely different from, though still depending upon, what might be conceived of as a mere combination or addition of the attributes of the various individual parents used; there were usually excesses in size, vigor and other properties over those obtaining in either parent, and not infrequently the appurtenances of the hybrids were so superveniently extraneous as nearly or completely to dissemble those of the original strains. The inability to predict results from a knowledge of the properties of the parents used has always been a fascinating feature of hybridism. If we were not so familiar with the production of most of our common hybrid plants and animals (and which are not hybrid?) or if we should approximate precision in estimating their several qualities and accessories, as compared with those of the races that enter into their production, the novelty of their emergent properties would be so marked as to amaze us.

There are thousands of named varieties of the common dahlias, to suggest only one more case, and yet it is known that they have all been derived from comparatively few elementary strains. Such examples might be augmented from both biological kingdoms *ad infinitum.* In fact, as biologists generally well know, there is not any higher plant or animal, domesticated or wild, which is not, in some of its most essential aspects, the extraneous emergence of hybridism. It may not be too much to state that hybridity has been the efficient, ultimate agency by which the fortuitous, mutant properties of all

varieties of sexually reproducing organisms, including man, have reached, or may attain, whatever grade of supervenient emergency that they now or may in the future occupy, whether it be among the vast majority that perish, those that are suffered and linger awhile, or the presumably relatively few that through the operations of natural selection survive to carry on.

From the view-point here stressed even mental progression in animals and man may be regarded as so many levels of emergence, and with no more resort to the exigency of vitalism than is required in the consideration of the uniting of substances and the resulting supervenient products to which attention has already been directed. Societal forces, whether among insects or men, are also now recognized by ecologists and sociologists as being incomputable, impredicable, and following laws of their own which are usually different from, though depending on, those intrinsic in the lives and laws of their respective, individual constituents. Since "there is not on the planet a single animal or plant that does not live as a member of some biocenose" (societal emergence), and since each higher organism is, in itself, a supervenient emergent of the hybrid combination of hereditary characteristics and the genetic factors involved are incalculable in numbers, and new characteristics are continually coming into existence through mutations and old ones disappearing, it is not difficult to comprehend at least one thing about the future of organisms on the earth, and that is the futility of prediction or prophecy with respect to the possibilities of any individual or society, whether of plants, animals or men.

Furthermore, from the view-point of emergent evolution "each higher quality (emergence) plays the part of deity to that which lies below it." This rather advanced view is more adequately developed by Alexander in "Space, Time and Deity" and by C. L. Morgan, to whose reasoned discussions the interested reader should by all means turn. It may not be without the bounds of reason to suggest that this supposition is of the utmost importance, for it may actually render deityship, perhaps of a kind not entirely unacceptable in religion, reasonable and tenable to the most rational and practical minded of men. This may possibly be at least part of the way out of the existing *impasse,* which is admitted on all sides, and without serious violence either to science or religion; a means of approximating "the world as man would like it imaginatively [*even actually*] superimposed on the world as it really is."

The idea of emergent evolution has been received with auspicious cordiality in America, as well as elsewhere. Wm. Wheeler, G. H. Parker, H. S. Jennings, H. H. Laughlin and other leaders in science and thought, besides those already mentioned, have espoused and supported the hypothesis to some extent and in one way or another. In recent publications, Dr. Jennings has hailed "the doctrine of emergent evolution as the declaration of independence for biology." Undeviating allegiance may now be devoted to the experimental method with the living as it is with the non-living. The biologist no longer needs to apologize for not accepting "the prevalent dogma that the only method of learning about the organic is to study the inorganic." What is here implied concerning the liberation of the biologist may as well apply to the situation of any reasonable, educated person. Thus the apprehension of emergence, or emergent evolution, is apparently finding a welcome, in one way or another, among a number of philosophers as the more competent course, avoiding facile, pretentious and resourceless mechanism, on the one side, and crude, irrational and insolvent vitalism on the other.

THE REIGN OF PROBABILITY

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I

THIS paper discusses one of the classical fields of mathematics—the theory of probability—tracing very briefly its content and significance. It is hoped that the reader will be convinced that there is no other branch of mathematics which touches science and every-day life at so many and such important points. In fact, it will be argued that the theory of probability plays such a fundamental and such an all-inclusive rôle that one is justified in the paraphrasing of the title of Lord Haldane's recent book, and in the speaking of the "reign of probability."

II

The theory of probability had an unsavory origin. Nearly four centuries ago a professional gambler, Chevalier de Méré by name, discovered (presumably from his check stubs) that the odds were better than even that a 6 appear at least once in four successive throws of a die. His clientele, however, seem to have tired of this particular game, and de Méré tried to invent a new one to stimulate the market. He reasoned that two dice can show six times as many combinations as can one die; and that therefore in 6×4 or 24 throws of two dice, the odds should be better than even that a pair of sixes would appear at least once. Unfortunately for his bank balance his reasoning was quite unsound, the number of throws he could have safely bet on being actually twenty-five rather than twenty-four. De Méré consulted the philosopher-mathematician Pascal, who corresponded on the problem with his friend Fermat; and the junior elective, Mathematics 118 (Tuesday and Thursday at eleven with a third hour to be arranged), was founded.

The early development of the theory was closely connected with such problems, and even to-day the student of the subject starts out by learning how to play poker and how to shoot craps. The probability of an event is defined as the number of cases favorable to the event divided by the total number of equally likely cases. Thus the probability of throwing a head with a coin is one half, since there are two equally likely cases, only one of which is favorable. The probability of drawing a club from a deck is one fourth, since there are fifty-two cases, thirteen of which are favorable. To consider a somewhat more complicated example, choose a letter at random out of a box of mixed type. What is the probability that one draw the letter "h"? It is 1/26, since there are 26 equally likely letters, only one of which is "favorable." What is the probability that the next letter chosen be "e"? It is again 1/26. What is the probability of thus spelling by chance the word "he"? According to a fundamental law, the probability of the occurrence of two independent events is the product of their respective probabilities. Thus the probability of drawing first an "h" and then an "e" is the product of 1/26 by 1/26 or 1/676. This problem has obvious and intriguing generalizations. Put a Hottentot in front of a linotype machine. What is the probability that he will compose, by chance, Keats' "Ode to a Grecian Urn"? Blindfold George Bernard Shaw and put him in front of a typewriter with interchanged type bars. What is the chance that he would reproduce one of Bruce Barton's uplift sermons?

The entire elementary development of the subject is a process of inventing convenient analytical ways of applying

the definition of probability just stated and illustrated. A mere counting of equally likely and of favorable cases is possible for simple problems. But it is easy to construct apparently simple problems in which it is difficult to carry out this enumeration of total and equally likely cases. For example, an even number of balls is drawn out of a sack containing half white and half black; what is the probability that the sample is half black and half white? Again, two integers are chosen at random: what is the probability that they be relatively prime? Again, n balls numbered from 1 to n are mixed in a sack and drawn one at a time; what is the probability that not a single ball be drawn in its proper order? That is, what is the probability that never is a ball labeled "r" drawn on the r-th draw? The numerical answer to this last problem is, for reasonably large n, the number 1/e, where e is the familiar Naperian base 2.71828. . . . This result has been recently rephrased in the following post-prohibition form. "If every inhabitant of Chicago got drunk and went home by guesswork, the chance that at least one would get back to his own house is almost two out of three."

After one obtains, from such interesting but comparatively trivial examples, a facility in the elementary technique of the subject, he proceeds to the study of those more refined and powerful methods which enable him to deal with cases involving a very large number of possible events. Here the addition process of enumeration is replaced by integration, and the student meets the so-called probability curve. One studies, at this stage, the theorem of Bayes, which deals with the probability of the causes of events; and he applies the theory of probability to problems of measurement to obtain a theory of errors. One proves the theorem, due to Bernoulli, which is usually referred to as the law of great numbers. This law admits that no one knows whether a single coin will come up heads or tails, but states that as one repeatedly tosses a coin, the probability gets closer and closer to one (certainty) that the ratio of heads to total number of trials will differ from one half by as little as one pleases. If a million coins be tossed, one can expect that the ratio of heads to total trials will be near 0.5. In fact, what is the chance that this fraction will differ from 0.5 by as much as 3 per cent.? The probability of this occurring is so small that such a deviation would actually occur, on the average, only once, were every person on earth to perform such an experiment ten thousand million times a second for 10^{18} centuries.

At this point in his study, the student begins to meet problems that sound less like Monte Carlo and more like the laboratory, the office and Main Street.

1. A grocer sells, on the average, 50 boxes of "Cream of Wheat" a week. How many ought he to stock every Monday morning in order to reduce to one chance in ten the probability that he will have to refuse a sale?

2. What is the probability, in an elimination tennis tournament involving thirty-two players, that the best and next best player will actually meet in the final contest?

3. The "Big Bertha" shells fell in Paris at the points indicated on a given map. What is the probable direction of the gun?

4. A company manufactures millions of electric light globes, which are shipped in cartons of one hundred globes. What percentage of cartons and what percentage of lights in a carton should be tested to reduce to one in a thousand the chance that there is more than one defective globe in each carton?

5. Two separate field parties come back to the office with sets of surveying measurements taken of the same distances and angles. How should these data be combined to produce the best result? If two thousand dollars is available for raises in salary, these raises to be based solely on field proficiency, how should the sum be apportioned between the two parties?

6. Data are taken in the laboratory and the plotted experimental points seem to lie roughly on a straight line. What is the best straight line?

7. Curves are drawn showing variation of prices over a long range of years. Do or do not the wave-like fluctuations in these curves possess a truly periodic character?

8. Fifty dogs which have been infected with a disease are given a treatment which it is desired to test. Thirty of the dogs get well, and the rest die. A control group of fifty more dogs is infected but not treated; and twenty-three of them die. Does the experiment give any basis for confidence in the treatments?

9. Three thousand university freshmen are given entrance and intelligence tests in various subjects. Their entire university record is later tabulated along with these test grades. What correlation exists between the prediction of the tests and the actual subsequent performance? Do these data indicate a sound basis for advising incoming freshmen?

10. A state government is setting up a Teachers Saving Act. What income must the fund derive from taxation in order that it be statistically sound; that is, in order that the probability be reduced to a safe level that a series of unusual demands bankrupt the fund?

11. In a fertilizer experiment, one fourth of the total land to be used is to be kept unfertilized as a control. How should the total land be geometrically divided up into experimental plots and control plots?

12. What is the probability that every member of a jury will, in the face of confusing and doubtful evidence, vote wrongly?

13. In the city of Edinburgh 49 per cent. of the girls of school age have fair hair and blue eyes, while in Glasgow 51 per cent. have fair hair and blue eyes. Is this discrepancy large enough to be significant?

14. A given quantity is measured ten times under uniform experimental conditions. One of the results differs from the average by three times as much as does any other result. Is one justified in discarding it?

15. Taking account of the growth for the last one hundred years, what is the probable population of the United States in 1950?

16. White female rats and black male rats, both from a mongrel strain, are bred. Each succeeding generation is produced by choosing white females and breeding them with white males of a pure white strain. What is the probable percentage of black rats in the r-th generation?

17. In a certain gas at a given temperature and pressure, what is the probability that a molecule will have so great a velocity that it is capable of permanently leaving our atmosphere?

18. Three curves are plotted, one showing the sun-spot activity, one the variation in rainfall and one of the variation in the price of wheat. Do these curves furnish a basis for concluding that these phenomena are, to any extent, causally related?

19. Considering the extent to which stellar velocities approximate the Maxwell-Boltzmann distribution which characterizes a perfect gas, what is the probable age of the universe?

One could extend such a list of questions indefinitely. Many such, to be sure, can not be answered categorically. In many cases the theory of probability teaches that there is not a single, but many answers; in other cases, one learns that the data are not sufficient, but one nevertheless obtains all the conclusions that the given data warrant. Even in the cases where answers are impossible the theory of probability often greatly helps to clarify one's thinking by pointing out just why the question is vague or unanswerable.

The questions put above indicate that the theory of probability can be applied to many fields of investigation; and this is indeed true. It is easy to see what is the general basis for this extensive applicability. Man's intellectual life is characterized by a sequence of observations of things or relations, and of inferences drawn therefrom. These inferences fall in two classes: inferences which may be classed as logical necessities, and those which may not. The first sort exists chiefly in books on logic (or on mathematics!). One must have exact and sufficiently extensive knowledge to permit conclusions to be drawn by a mere application of the canons of logic. If the information be not exact, or not sufficiently extensive, then the inferences which it warrants are arrived at through the theory of probability. When one states, "A biped has two legs" (definition); "a man has two legs" (exact and sufficiently extensive information), one is then in a position to conclude, irrevocably and unassailably, that man is a biped. But when one says, "I measured the side of this square ten times and

obtained slightly different results whose average is 13.26 cm. What is the area?"; or when one says, "I am thirty-six years old and in sound health. How long will I live?"; or when one says, "The kettle has been put on the stove. Will the water boil or freeze?"—in all these cases one is attempting to argue from an insufficiently accurate and from an insufficiently extensive body of data. One can not legitimately ask for *the* conclusion. He can merely ask (and then perhaps vainly) for the probability of various conclusions.

Thus it is clear that we are usually interested in situations where our data are not of such character as to lead directly and unequivocally to our conclusions. So the theory of probability plays, whether recognized explicitly or not, an important rôle in a large proportion of our scientific and of our general activity. This will be made more clear if we consider, even though briefly, some applications of probability theory.

III

As a first and very familiar illustration, we may note the application of probability considerations to the gamble which every man makes with death. We all know that an insurance company could not risk any considerable proportion of its assets on the life of one man. But so regularly and inevitably do the predictions of probability work out when applied to large numbers that the income and outgo of a large insurance company are more stable and predictable than the income and outgo of most commercial concerns. This application of probability to the basic theory of all types of insurance is an old story to us, yet few realize the size or importance of the institution of insurance. The population of our country is at present committed to pay the premiums on over one hundred billion dollars' worth of life insurance alone, this vast sum being about one third of our total national wealth. The social significance of this large-scale application of probability theory was recently expressed by Ex-President Coolidge, who said, "The life insurance organizations ought to be a source of great pride and satisfaction to the country at large. They are a stupendous force enlisted on the side of public health, sound finance, good government, economic betterment and moral well-being."

IV

A great branch of probability theory is the body of doctrine known as "statistics," which is being widely used to-day in many quantitative and semi-quantitative fields of experience. Statistical theories fall under three headings: the theory of sampling, correlation theory and the theory of dispersion. The theory of sampling studies the extent and reliability of the conclusions about the original source which one can draw from a sample. Correlation theory studies the nature and degree of inter-relationship between measurements of two or more attributes. Dispersion theory is really a part of the theory of sampling, and treats of the inferences one can draw from sets of samples concerning the homogeneity of the sources from which these samples are drawn.

The theory of sampling, for instance, considers such a question as this: Shipments of fruit from a certain shipper arrive, on the average, in 95 per cent. sound and salable condition. A certain shipment arrives, and a small sample is examined and found to be 20 per cent. unsalable. If examination of the whole shipment is not feasible, what is a fair price? Correlation theory considers such a question as this: University grades and post graduation salaries are plotted for a large number of individuals. To what extent may a student who earns high grades expect a large salary? Dispersion theory considers

such a question as this: Heights are measured of 1,000 Americans, 1,000 Englishmen, 1,000 Frenchmen and 1,000 Norwegians. Does the dispersion existing within these sets of samples indicate that height is attributable more to racial or to individual circumstances?

It is clear that such techniques are valuable to a considerable range of investigators. The educational psychologist, the biometrician, the geneticist, the economic student of prices and price trends, the political economist who is interested in various theories of representation and of voting, the doctor who is studying epidemics or the effectiveness of various preventive measures such as inoculations and vaccinations, the ballistics officer at the front, the efficiency engineer in the great industries—all these must make use, at every turn, of the theories developed in probability or in statistics.

V

Let us consider in somewhat more detail such quantitative sciences as physics and chemistry. First of all, quantitative sciences, as the name indicates, involve measurement. No human measurement is perfect, and hence all measurements involve errors; so that the moment any discussion involves measurement it involves the theory of probability in a fundamental and inescapable way. In fact, all questions of properly weighting and combining discordant data, of computing probable errors or relative precisions, and of fitting curves, are questions belonging to the theory of errors. Thus all the measuring sciences have to come to the Monte Carlo mathematician for his indispensable assistance.

The kinetic theory of gases is one of the spectacular applications of pure probability. Starting with the concept of a gas as a hoard of elastic spheres, one calculates the probability of various sorts of collisions, and is led to a theory for distribution of molecular velocities, for pressures, for viscosity, for diffusion and conduction processes, for Van der Waal's equation and for entropy and other thermodynamic concepts. Similar applications of probability lead to theories of Brownian movement, diffuse dispersion of light by molecules, double magnetic and electric refraction of fluids, opalescence, etc. As a growth out of the kinetic theory of gases there has resulted a most fertile union of probability and mechanics, this combined theory—the so-called statistical mechanics—being able to deal with such basic matters as specific heats, Nernst's Heat Theorem, thermionics, magnetic properties of gases, properties of dilute solutions, chemical kinetics, thermodynamics of stellar interiors, etc.

In connection with researches in statistical mechanics, Eddington has recently brought forward a most curious and interesting idea. This idea is profound in its philosophical implications and somewhat involved in its technical details, but its main features may be easily explained. The idea relates to our concept of time, and particularly to the unidirectional character of time. Philosophers have naturally been much concerned with the concept of time and with the fact that it sweeps ever onward and forward, never stopping and never retracing its steps. Scientists, however (at least up to the time of Einstein's 1905 paper), have had comparatively little concern with the concept of time. They have simply accepted the variable t as they have accepted other attributes of the external world. Physicists, in particular, have been curiously uninterested in the statement that t always increases. In fact, most of the fundamental theories of the physicist are completely indifferent as to whether time proceeds forward or backward. Under the equations of mechanics, for example, a planet moves about the sun in a certain definite path which it traces out

through the ages; but if one could suddenly reverse the motion of the planet, it would proceed to retrace its path, undoing day by day just what it had previously done. This illustration is typical of all those phenomena which are governed by the laws of mechanics; for in the equations expressing these laws the replacement of $-t$ for t does not result in any change whatsoever in the form of the equations. This indifference to a reversal in time is not restricted to mechanical laws. The laws of physics may, in fact, be divided into so-called unitary laws and statistical laws. The unitary laws govern such unitary phenomena as the impact of two particles, the action of one charge on another, the emission or absorption of light by a single atom, etc. The statistical laws, as the name indicates, govern the behavior of huge assemblies of particles, charges, atoms, etc. All the unitary laws have the property just illustrated for the laws of mechanics—*viz.*, they are indifferent to the distinction between $-t$ and $+t$. There has been some feeling that physics was, so to speak, falling down on the job if it could not produce satisfactory unitary laws, but had rather to take recourse to statistical laws. A statistical law states what will happen on the average, while a unitary law states what will happen in particular; and it is natural to feel that the particular statement is much the more informed and satisfactory. Therefore, physics has been primarily engaged, up until very recently, in an attempt to determine unitary laws for all phenomena, and these unitary laws, as was just pointed out, work quite as well backward as forward. That is, physics has been committed to an attitude of actual indifference toward the question of the unidirectional nature of time. In the last few years, however, physics has grown somewhat skeptical concerning the probable success of its proposal to find unitary laws for all phenomena. It begins to look as if the more fundamental laws are actually the statistical laws—the probability laws—which describe the probable behavior of large groups of units.

We are now, at last, ready to consider the idea of Eddington referred to above. He points out that statistical laws are not indifferent to the distinction between $-t$ and $+t$. In fact, he suggests that the unidirectional character of time—"time's arrow"—is merely our recognition of the fundamental non-reversible character of such statistical phenomena.

A consideration of one of Eddington's examples will make the idea more clear. If one takes a new deck of cards from its original wrapper, the suits are all separated and the cards are in order. If one now shuffles this deck time after time the cards become disarranged. It is an essential feature that the shuffling is applied to a large number of cards. One can not shuffle a single card; and the more cards there are, the longer can shuffling proceed without reaching completion. This shuffling process has removed a certain feature—*viz.*, the original arrangement—and it is very unlikely that any subsequent shuffling will ever reinstate the original order. Thus Eddington views shuffling, or rather the introduction of a random element by means of shuffling, as a truly non-reversible process. This non-reversibility of the process is a characteristic of phenomena relating to a large number of unitary elements or events. Unitary processes, we have seen, go backward as well as forward; but the shuffling of a statistical ensemble goes only forward. If this introduction of the shuffled character or random element into the material world is a process which can only proceed forward and never backward, then it furnishes us with a criterion for the forward passage of time. For example, suppose one has two instantaneous photographs, A and B, of a part

of the universe, taken at two different instants, t_A and t_B. If photograph A shows a more shuffled universe than does B, then one concludes that t_A is a later instant than t_B. The illustration would be a better one if we considered not snapshots but moving pictures, for we should by rights consider shuffledness of velocities as well as disarrangements of positions. The moving picture also makes it more clear to us that it is essential that we be dealing with a statistical situation which can be shuffled rather than with a unitary process which can not. Thus, if one had a moving picture of a single swinging pendulum, he could not possibly tell whether the film were being run through normally or in the reverse direction; but if one had a picture of a swimmer diving into a pond, he could tell at once whether the direction of the action be normal or reversed. The criterion for this judgment should not, in fact, be the motion of the swimmer's body, for it is conceivable for him to be propelled up out of the water. But the motion of the "splash" and the statistical shuffling of the positions and velocities of the water particles—this is a non-reversible process which can serve as a criterion.

Eddington develops this idea and attempts to make such considerations serve as a sole and satisfactory basis for our concept of "time's arrow." Such a view-point is probably unsatisfactory to a metaphysician and is attended by grave difficulties for the physicist. Whether or not the idea turn out to be a sound one, it is, nevertheless, of great interest to us in the present connection, for it indicates fairly the sweeping significance which is assigned by modern physical theories to probability considerations.

VI

Modern quantum theory deals with the fundamental questions of absorption and emission reactions between atoms and radiation, making use of the wave mechanics of de Broglie, Schrödinger and Heisenberg, and the still more powerful and more abstract transformation theory of Dirac and others. This theory probably constitutes the most penetrating attack man has yet made into the delicate and minute secrets of nature. The theory is, in its presently accepted form, essentially statistical in nature, using probability concepts as its fundamental concepts. It is neither desirable nor possible to attempt to trace here in any detail just how these probability considerations enter, but it is easy to see that they do enter. In fact, all microscopic unitary processes of nature, such as the motion of a single electron or proton, the emission or absorption of light by a single atom, the impact between two particles, etc., are studied, following the Schrödinger scheme, by evaluating at every point of space and at every time a certain "wave function" psi. In the early stages of the new theory, physicists everywhere clamored to know what psi was. It has turned out that, say in the problem of the collision of two particles, the value of the square of this wave function at any point and at time t is the measure of the probability that one of the particles be "at" this point. This simple statement is of overwhelming significance as regards the general thesis we are defending. We are all well aware that statistical discussions lean heavily upon probability theory. But we are apt to think of such discussions as having a secondary significance. Behind the statistical or average behavior we have liked to think of the unitary processes; and we have viewed these unitary processes as strictly open-or-shut affairs, with which probability has no concern. It appears that we have no modern support for this feeling. All these unitary processes are themselves subject to chance. When a particle collides with a second, we can

not say, with contented and smug satisfaction, that the particle will after t seconds be in a certain definite spot. We have to content ourselves with saying what is the probability that it will be at the spot in question. One can, if he likes, interpret this as a failure of our attempt to find a unitary law; or he may merely say that the unitary law is itself to be phrased in the language of probability. That is an unessential matter of mere terminology. The inescapable fact is that every process that comes properly under the purview of physics is an experiment in probabilities. It means that quantitative science is a giant game of cards, and that the sort of mathematics which is most fundamentally applicable to nature is the old unsavory Monte Carlo mathematics.

VII

Thus we have seen that the theory of probability furnishes working tools for many branches of science, the fundamental concepts for others. It seems impossible to escape from this mathematical goddess of chance. When one says that he thinks that he will be here to-morrow, the theory of probability bears on the remark from a good many angles. There are, first, the obvious chance events that might conspire to make it possible or impossible for him to be here. But the matter goes deeper than that. Let us examine the various phases of this assertion "I think I will be here to-morrow." "I think"—the theory of probability has contributed so much to the subject of the logic of inferences that one might well say that the theory of knowledge itself rests in considerable part on probability theory. In fact, Laplace, the great master of this art, said in the introduction to his "Théorie analytique des probabilités," "Strictly speaking one may even say that nearly all our knowledge is problematical; and in the small number of things which we are able to know with certainty, even in the mathematical sciences themselves, induction and analogy, the principal means for discovering truth, are based on probabilities, so that the entire system of human knowledge is connected with this theory." "Will be to-morrow"—well, we have spoken of the connection between probability and the concept of the forward flux of time. "Here"—only the theory of measurement can tell one the difference between *here* and *there*. And finally, the theory of probability, as the human biologist would insist, has a good deal to do with what "I" am. To each human being is dealt out, from the two parents, twenty-four pairs of chromosomes. Using these forty-eight biological units, one can build up a number of combinations which is something over ten million times a hundred million; and all the various genetic relations in which these characterizing influences may be passed on are subject to the laws of chance. In fact, according to Guyer, "The law of probability is the fundamental principle around which biometrical investigations revolve." If we wish to push further back than our immediate parents, and if we forsake the realm of sober science, then probability plays a more whimsical rôle in determining what "I" am. If great-grandfather William had only taken along his umbrella, he would not have been soaked in that sudden cold shower, and "I" would be a different "I," with no scar tissue on my lungs. If great-great-great-grandfather Jonathan had only stumbled onto the right path, instead of the left, that famous time he wandered home drunk, Elizabeth would never have known, the engagement would not have been broken, and "I" would likely be tall and handsome, blond and blue-eyed.

VIII

Thus at our birth and at our death, in our moments of whimsical fancy and

in our most serious moods of philosophic or scientific contemplation, the theory of probability plays a basic rôle. One finds it natural to ask, then, whether there is any escape from this tyranny of chance. It seems, at the outset, a fundamental paradox that one should speak of the laws of chance, since chance and law are to most of us antithetical concepts. We are up against something more than a mere paradox, however, if chance is not only to lurk always behind our shoulder ready to push us into accident, but is also to be the central feature of all our trusted and well-ordered schemes of science and society. Is there no escape from this specter of an ever-present devil shaking dice?

A few years ago I think the answer to this question was "Yes." We believed that events were reckoned as "chance" events merely because the underlying causes were so many and so intricate that man's intelligence had not as yet been able to effect a complete and rationalistic analysis. Thus the tossing of a coin was a chance event. Why was it a chance event? No one doubted that the equations of mechanics possess a unique solution. Every one thought that if we were but clever enough we could make a complete analysis of all the intricate features of muscle-tension, position in the hand, weight, form, air resistance, etc., so that the tossing of a coin would be elevated from the unrespectable level of chance events to the sacrosanct classification of good old sober, logical, cause-and-effect phenomenon.

The present view should be, I think, that this tyranny of chance, this reign of probability, is both all-inclusive and inescapable.

There are two main reasons why we can not see, at present, any probable relief from probability. In the first place, we have just mentioned that, on the older view, one always had the hope of resolving any complex situation, apparently subject to chance, into constituent simple situations. These simple situations, one believed, would then be quite free from the taint of chance. Modern physics, however, does not take this view. It is increasingly skeptical of the possibility of always resolving the complex in terms of the simple; and even when the phenomenon in question can be analyzed in terms of unitary processes one has gained nothing. For these unitary processes themselves are chance events.

There is a second reason, moreover, why we can not just now see any escape from the tyranny of chance. This reason is based upon ideas which have found no expression above, and which we can not here expound in any detail. Heisenberg has recently announced, in his quantum theory investigation, a new principle known as the principle of indeterminism. This principle places theoretical limits upon the accuracy which we may attain in our measurements of the external world. In particular, it refers to the accuracy with which it is possible for us to make simultaneous measurement of the position and velocity of a particle. One had supposed, previously, that there was no theoretical reason why such a simultaneous pair of measurements could not be refined indefinitely; but such, according to this principle, is not the case. There is a certain minimum joint vagueness. We may, to be sure, refine as much as we choose *one* of the measurements—say the measurement of position—but if we do, there is an inescapable decrease in the accuracy with which we measure the velocity; and *vice versa.* This indeterminism is no matter of ordinary experimental error. It arises from the basic fact that we have no knowledge of the world save as we observe it. Observation is a partnership affair, active rôles being played by both observer and

observed. The observation itself, moreover, has an effect on the thing observed; and it turns out that it is never possible to reckon exactly what this effect has been.

It has not yet been made clear why this principle of indeterminism is important to the present argument. The reason is this. When one measures with a certain accuracy the position of a particle to be thus and so, we have said that he can not also measure the velocity to be exactly thus and so. The fact is that he can merely measure velocity and then conclude what is the *probability* that the velocity is thus and so. For example, if the position be measured with perfect precision, one would have to content himself with the statement that all values of the velocity were equally probable. This principle thus means that such is our relationship with the external world that all our data are of necessity probability data. This is the most fundamental consideration we have listed. If this be true, then it is unimportant to ask whether or not all phenomena can be resolved into unitary processes, or to ask whether or not these unitary processes are themselves statistical in nature. To ask whether or not this be true is, in Bridgman's operational sense, meaningless, for the fact is that we seem condemned to observe statistically. Whether or not nature is playing a giant game of cards, our observational spectacles are such that we always see her doing so.

Science does not lay down permanent decrees, but is governed, rather, under Trotsky's principle of a permanent revolution. It is contrary to the whole accumulation of scientific experience to say that a position, occupied by science to-day, represents an ultimate and permanent position. There may be lurking, just around to-morrow's corner, a new and clearer view-point which will invalidate the present position. But the present position is, I believe, here fairly stated. The first part of the twentieth century (and we know not how much more) should be known as the reign of probability.

LUNG-FISH

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LUNG-FISHES are among the strangest of creatures. They are, strictly speaking, fishes, but they differ from most members of this class in possessing lungs in addition to gills, and a heart and circulation adapted to the double respiration of air and water; hence their scientific name, Dipnoi. The biologist is interested in them because of their extraordinary character and life habits, and the paleontologist because they are the straggling survivors of an archaic group of fishes which played an important part in the story of evolution. Once numerous and widely distributed in the fresh waters of the Paleozoic continents, they are reduced to-day to *Epiceratodus* of Australia, *Lepidosiren* of South America and *Protopterus* of Africa. *Protopterus* lives in the River Gambia, the Congo and the rivers and lakes of equatorial east Africa. There are three species which resemble each other very closely.

Protopterus looks like an eel, and in the aquatic phase of its life it lives very much like any other fish except that it rises to the surface of the water regularly to breathe air. It is during the annual dry season of the tropics that the lung-fish comes into its own. Those individuals that are trapped in the swamps by the recession of the water bury themselves in the mud and pass into a state of estivation which persists until the rising waters of the "big rains" set them free again. The mud nest consists of a burrow extending from twelve to eighteen inches underground. This burrow is formed by the repeated journeys of the fish to the surface to get air while the mud is soft. As the last water dries out of the burrow the fish curls itself in a close coil at the bottom with its head pointed up the burrow, and slowly passes into a state of sleep that approaches suspended animation. The estivating fish covers itself with a parchment-like cocoon formed of dried slime secreted from its dermal glands. This cocoon completely envelops the animal except at the mouth, into which it extends as a short, open tube and through which

FIG. 1. THE FINS OF *PROTOPTERUS* ARE DEGENERATE FILAMENTOUS APPENDAGES, USELESS FOR CRAWLING OVER LAND IN SPITE OF ITS ESTIVATING HABITS AND AERIAL RESPIRATION.

respiration is carried on. So tightly is the lung-fish encompassed by the cocoon and adjacent mud that there is not the slightest room to move; it is just as effectively imprisoned in the hard mud as though it were buried in concrete. There is probably no other animal in the world that becomes completely immobilized for such long periods of time. There is no possibility, of course, of obtaining food in its mud prison, and it is forced to live upon such fat as is stored in its body and upon the body tissues themselves.

The natives of Africa like to eat the lung-fish. They catch them in nets in Lake Victoria and in basket traps in the swamps and streams. What is probably the largest lung-fish on record was caught by native fishermen in Lake Victoria. This specimen is preserved in the Nairobi Museum of Natural History. It is seven feet long and has a head, if memory serves us, which must be twelve inches across. This fish was probably over one hundred years old. During the dry season the natives also dig the estivating fish out of the mud. They search the water-courses and swamps for the burrows, and thrust a stick into every suspicious looking hole. If the end of the stick smells of fish on withdrawal, the helpless victim is disinterred.

In years past numerous small specimens of estivating lung-fish have been dug out in Gambia with the mud nest intact and shipped to England, Germany and the United States. Some of these have been awakened from estivation by immersion in water, and kept in aquaria for years.

Through the favor of the John Simon Guggenheim Memorial Foundation we collected a number of active lung-fish from Lake Victoria during the summer of 1928 and brought them alive to New York. Some of them were induced to enter into estivation by placing them in mud which was allowed to dry out at room temperature. At the end of twelve to fifteen months a few specimens were disinterred for physiological study.[1]

Since we did not wish to waken them we did not put the estivating lung-fish into water, but instead carefully cut away the rock-like walls of the nest and removed the animal with as little disturbance as possible. The lung-fish were in a state of profoundest sleep or inhibition. This sleep was not dispelled by handling them, and they could be kept in a metabolism chamber for days or weeks without awakening. When placed in water, however, they are wakened in a few hours, probably by asphyxia, for they are unable to breathe without rising to the surface for air. The sleep is apparently of a nervous rather than chemical origin and appears to be induced by the prolonged immobilization of the animal in its rigid prison. We know that all the higher animals sleep at some time, and that this sleep has come to be a period of physical and nervous rest that is necessary for continued health and activity. This is probably true of all animals. We know that insects sleep, sometimes so profoundly that they can be picked up without being wakened, while other animals, such as wild mammals, birds, etc., sleep so lightly that they are usually alarmed into full activity by our approach. There are possibly some fish that sleep while swimming (mackerel), but others hide under stones, among grasses or beneath the sand during parts of the day or night, and remain physically inactive for considerable periods of time.

It is obvious that certain conditions are usually necessary for sleep in the higher animals, such as the absence of unusual sounds and other external stimuli. But there are also important internal factors that may work actively to induce the sleep. It is not yet clear to what extent this condition is due to

[1] *Journ. of Biol. Chem.*, 1930, 88: 97–130.

simple passivity in the higher nervous centers or to active inhibition of these centers. But the lung-fish, we may believe, lying perfectly still in its mud prison for long periods of time and shut off from all external stimuli, probably goes to sleep for much the same reason as the higher animals. But unlike other fish, the sleep is deep and not easily dispelled; it is more like that of a very tired child, quite indifferent to the outside world. When the floods again cover the land the lung-fish is quickly awakened, and breaking out of its cocoon, slips to the top of its burrow and swims free.

When the lung-fish buries itself in the mud it does not know how long it is to be imprisoned. Though the tropical rains come in an unfailing annual cycle, the high-water level varies from year to year and a particular piece of ground may remain dry for several years. It is to be expected, therefore, that the lung-fish would conserve its energy stores to the greatest possible extent. This is effected in part by the fact that the animal is forcibly restrained from any muscular activity, except such as is required for respiration and the circulation of blood. But there still remains the residual metabolism of the living tissues which continue to idle, so to speak, even while the animal is quiet and asleep. This fraction constitutes about four fifths of the total metabolism of the active, starved lung-fish. During estivation this residual metabolism is decreased, not abruptly, but gradually and apparently in proportion to the development of emaciation. Stored fat and tissue must furnish energy for the maintenance of life, and as these fuel-stuffs are burned the fasting animal loses considerable weight—about 25 per cent. during the first year. Since the rate at which the body fires burn decreases as the animal becomes more and more emaciated, it appears that an additional and equal amount of tissue will last at least

FIG. 2. A FIFTEEN-INCH LUNG-FISH IS SEEN CURLED AT THE BOTTOM OF A BLOCK OF MUD. THE COCOON HAS BEEN PARTLY TORN OFF IN CHIPPING AWAY THE HARD MUD. THE BURROW EXTENDS BACKWARD IN THE PICTURE. THIS FISH HAD BEEN IN ESTIVATION FOR FIFTEEN MONTHS.

twice as long. It may reasonably be expected that the estivating lung-fish can live for three to five years, and possibly longer. (There is no reason to believe that any other estivating or hibernating animal, not excluding horned toads, could live longer.)

One very interesting aspect of the estivating state is that little or no water is available. Water is constantly being lost by evaporation from the lungs as air is inhaled and exhaled. There is therefore an imperative need to protect the body from loss of water through the skin by the impervious cocoon, and to conserve this precious fluid otherwise to the utmost degree. For this reason urine excretion is completely suspended. All the non-volatile waste products formed from the combustion of the tissue pro-

teins, etc., which are normally excreted by the higher animals as fast as they are formed, are allowed to accumulate in the blood and tissues. Urea is the most important of these waste products and this substance accumulates in the body in relatively enormous concentrations. When the lung-fish is returned to water and resumes active life the accumulated metabolites are discharged through the kidneys and gills, about twelve to fifteen days being required for their complete excretion.

The concentration of urea in the estivating lung-fish rises to values (2 per cent. of body weight or better) greater than are known to occur in any other animal except the sharks and skates. In these the urea is an integral part of the blood and plays an important physiological rôle. There is, nevertheless, no evidence that the lung-fish is poisoned by the "uremic" state that occurs during estivation. It is well known that urea itself is not very toxic, and apparently any other injurious metabolites which might be quickly excreted by other animals are converted by the lung-fish into innocuous substances.

All things considered the lung-fish appears to rank among the hardiest of living creatures: *Protopterus* can survive in foul pools the temperature of which rises above 100° F. in the tropic sun, and they are completely independent of the respirable quality of the water in which they live; they can live for long periods without food and with complete cessation of kidney function; and though they can not live for more than a few hours under water, they can, paradoxically, live out of water—and without water—for months or years.

The way in which the lung-fish uses its lungs during the dry season recalls the probable circumstances under which air-breathing was first evolved. It is fairly certain that air-breathing was practiced by fishes long before any sort of efficient legs for crawling over land had appeared. The first air-breathers were apparently the ganoid fishes which lived in the early Devonian period. It has been concluded from several lines of evidence that climatic stress played the principal rôle in this important evolutionary step. The period in which the first air-breathing vertebrates were evolved was characterized by very arid conditions, broken only by occasional rains. The marked alternation of wet and dry seasons caused the masses of fresh water on the continents, widespread at flood time, to shrink and become foul during the ensuing dry season. The fishes trapped in the pools were forced to make greater and greater use of air. Thus the first lungs came into existence as adaptations to meet these difficult climatic conditions. Through one branch of the Devonian fishes these lungs were passed on to the ancestors of the terrestrial vertebrates, and through another branch to the higher fishes. But the latter have, for the most part, let the air-breathing apparatus fall into disuse, and in most of the modern fishes only a vestige remains in the closed-off air-bladder, or it has disappeared entirely. In the lung-fish, however, the primitive lung persists as such, and we may imagine that the surviving members of this group use it in much the same way as did their Paleozoic ancestors. In this view, the life habits of these fish show us how the vertebrates were freed from an aquatic life and set upon a course of terrestrial evolution.

THE PROGRESS OF SCIENCE

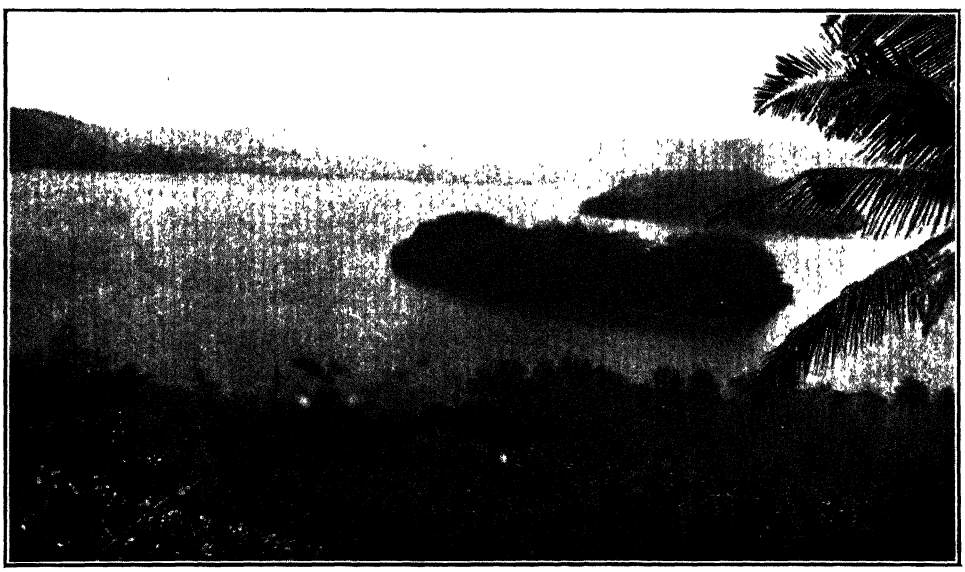
THE TOTAL ECLIPSE OF THE SUN

THE second total eclipse of the sun for 1930 occurred on October 21–22. The path of totality extended for nearly 7,000 miles across the South Pacific Ocean in a southeasterly direction. The eastern end of the path terminated in southern Chile just as the sun was setting. The width of the shadow was about fifty miles in the middle of its course, but narrowed down to a band of less than half this width at its extremities. The duration of the eclipse was only ninety-two seconds and it took place a little after nine o'clock in the morning on Niuafou Island, which was about four o'clock in the afternoon, eastern standard time.

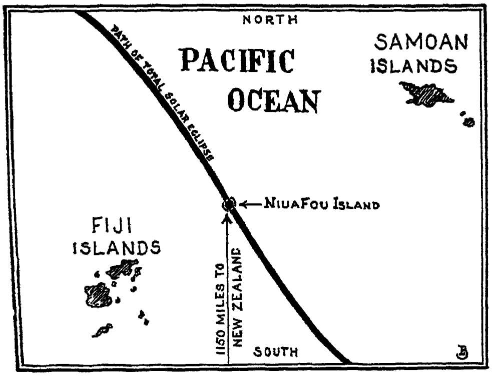
For most favorable observation it was necessary to choose a position in the South Pacific Ocean where the sun was not too near the horizon at the time of the eclipse. This condition was met on Niuafou, the little island from which the astronomical observations were made. This bit of land in the Tonga group is volcanic in origin, with a contour that is nearly circular, and is about three miles in diameter. A large central area nearly a hundred feet above sea level consists of a lake of brackish water. The island is under British protection and its population is composed of about 1,500 Polynesians and a couple of white traders.

The only important article of commerce is an exceptionally large variety of cocoanut which has never been successfully grown elsewhere. There is no good harbor and, as the shore is precipitous, the facilities for landing large packages are very poor. Mail for inhabitants is transferred between the island and the monthly inter-island steamer in sealed tin cans which are conveyed by swimming natives.

The United States Naval Observatory sponsored an expedition to make observations of the eclipse. Commander C. H. J. Keppler was in administrative charge. He was also in charge of the



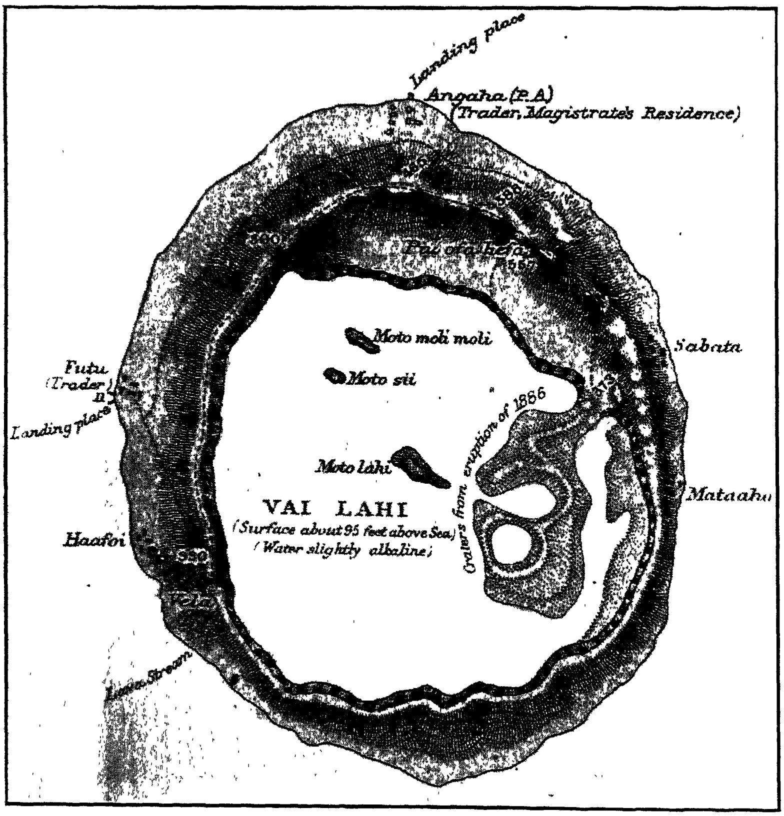
THE LAKE ON NIUAFOU ISLAND



Monthly Evening Sky Map
THE PATH OF THE TOTAL SOLAR ECLIPSE

successful expedition to Iloilo, P. I., in May of last year. Lieutenant H. C. Kellers, of the Medical Corps, was placed in charge of the health of the expedition.

Dr. S. A. Mitchell, director of the Leander McCormick Observatory at the University of Virginia, was scientific director of the party, and in direct charge of the spectrographic work on the flash spectrum. The personnel of the expedition was further made up of the following scientific men: Professor R. W. Marriott, of Swarthmore College, in charge of the large-scale photographic work on the sun's corona and of the photographs for the further study of the Einstein effect; Dr. J. J. Johnson, of the California Institute of Technology, in charge of photometric observations; Dr. Weld Arnold, of the American Geographical Society, Mr. B. P. Sharpless, of the Naval Observatory, and Mr. H. Fales, of Pasadena, assisted



NIUAFOU ISLAND
IN THE SOUTH PACIFIC OCEAN FROM WHERE THE ASTRONOMICAL OBSERVATIONS WERE MADE. IT IS OF VOLCANIC ORIGIN AND ABOUT THREE MILES IN DIAMETER.

A SCENE NEAR THE POST OF OBSERVATION

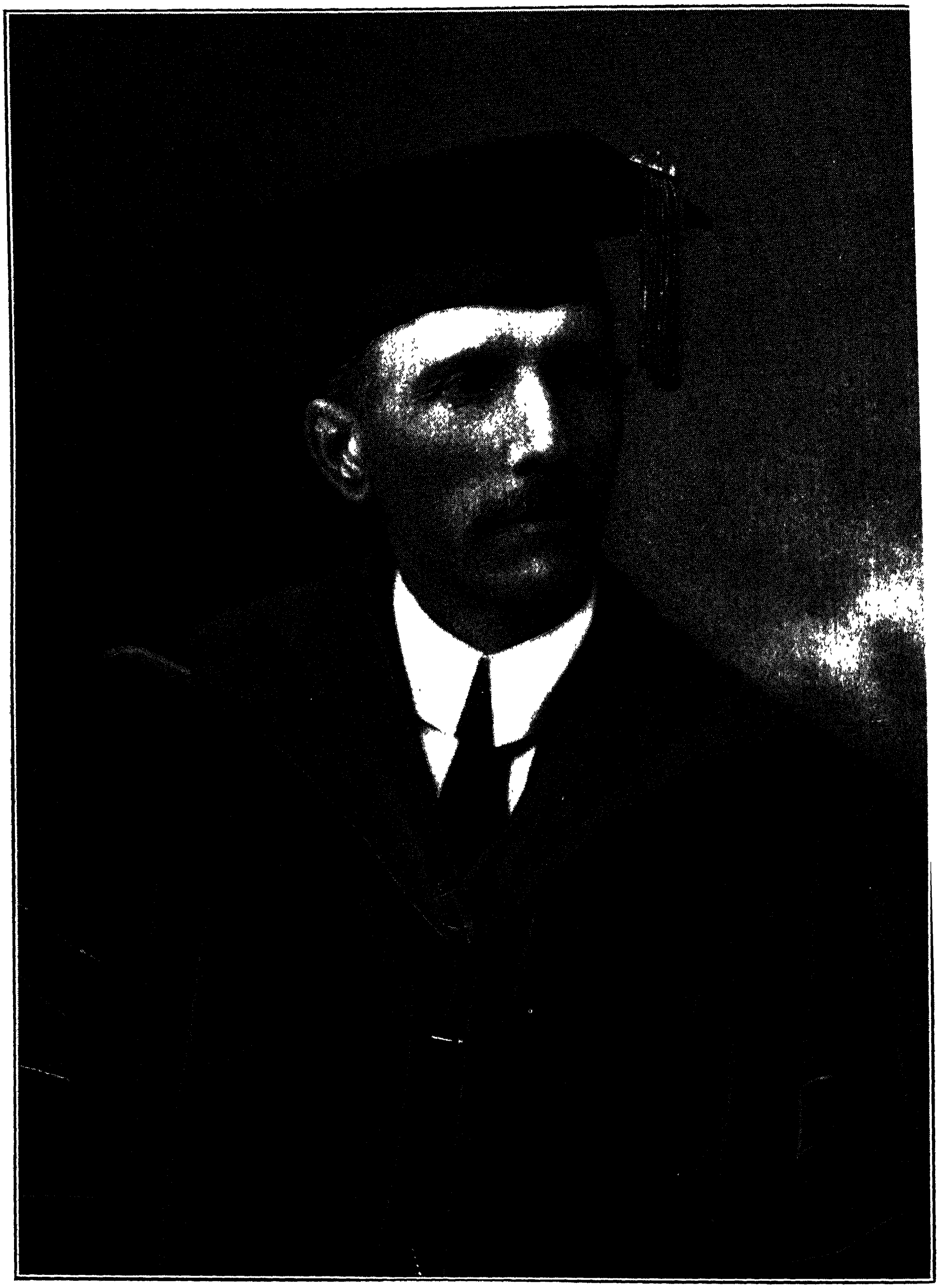
in carrying out the extensive program of observation; Dr. T. A. Jaggar, of the Hawaiian Volcano Observatory, accompanied the expedition to study the volcanic and seismic conditions. There was a serious volcanic eruption about two years ago, and such eruptions are said to occur about once in fifteen years. A New Zealand party of six astronomers joined the expedition on the island.

In addition to the scientific staff eleven enlisted men of the Navy and Marine Corps assisted in construction work and in taking observations. These men, selected from the personnel of the Battle Fleet, sailed from the Mare Island Navy Yard aboard the mine sweeper *Tanager* on June 25 and arrived at Samoa on August 9. Enlisted men included a rigger, an optical repair and instrument man, a carpenter to construct large cameras, an expert photographer, two general assistants, two radio operators, two cooks and an interpreter.

About 115 boxes and cases of scientific instruments and equipment were conveyed to the island, besides camp equipage and food supplies sufficient for twenty men for sixty days and about 8,000 board feet of lumber for the construction of various cameras. The largest of these cameras had a focal length of sixty-five feet and included a photographic developing room.

The objectives of the expedition included the following: a series of spectrographs including those of the flash spectrum; a series of photographs of the inner corona with the 63-foot camera, of the middle and outer corona with smaller cameras, moving pictures of the whole eclipse, including partial phases and totality, a special series of photographs of the star field near the sun for the corroboration of the Einstein effect, a series of photographs for photocentric determinations of the light of the corona, and observations for the times of contacts and of the shadow bands. The latitude and longitude were more accurately determined, and meteorological, volcanological, seismological, zoological and botanical data were secured as by-products.

The brief period for astronomical observation made it necessary for the observing parties to rehearse every movement with great care in advance of the eclipse.



FLORIAN CAJORI

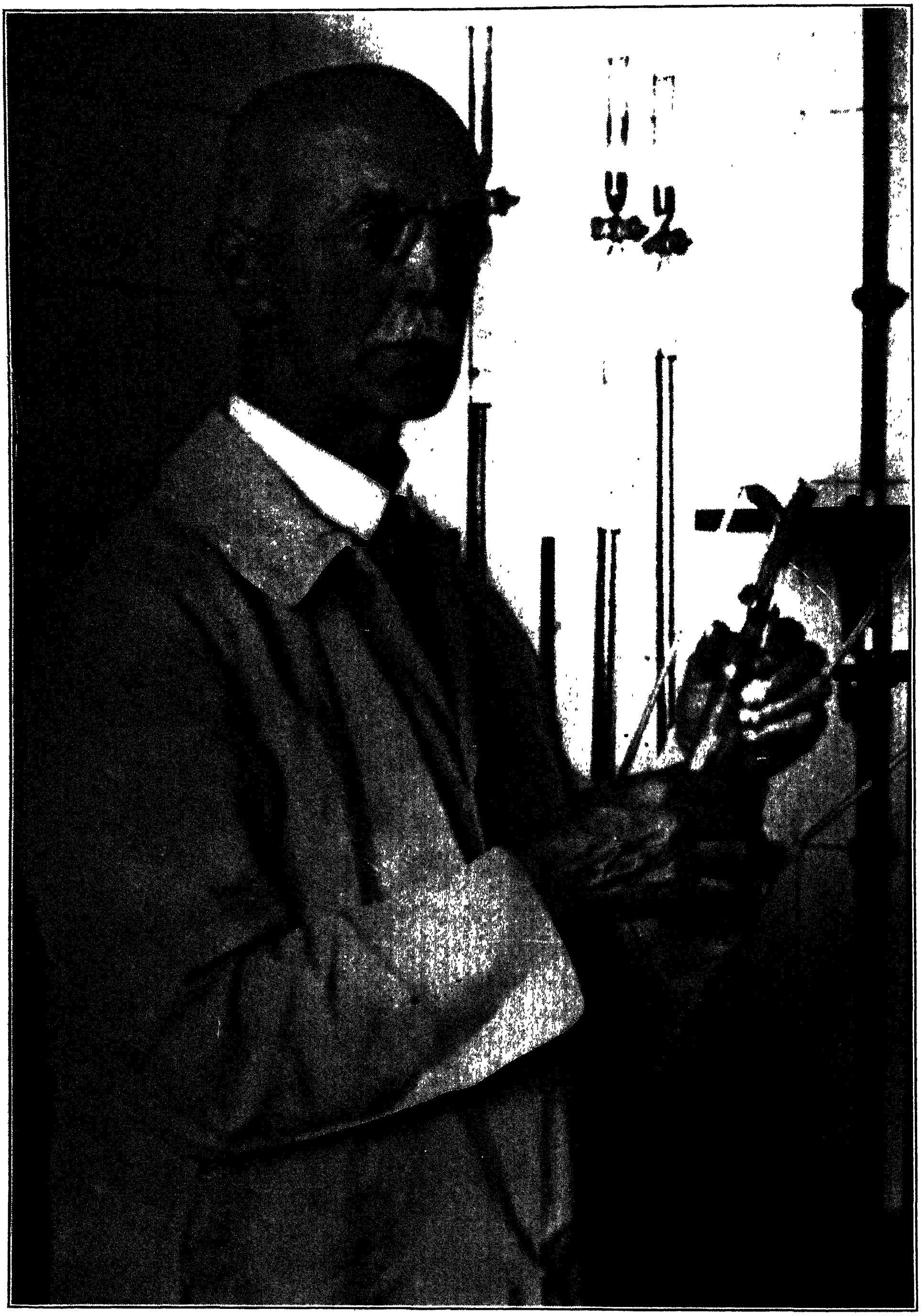
FLORIAN CAJORI

In the death of Florian Cajori, of the University of California, America has lost one of its most distinguished contributors to the history of science. The Scientific Monthly had the privilege of printing many articles by him, the last of these being on Johannes Kepler in the May number of the present year.

In an article printed in *Science* Professor David E. Smith states that Cajori was born at St. Aignan, near Thusis (Graubünden), Switzerland, on February 28, 1859, and came to the United States at the age of sixteen. Entering the University of Wisconsin, he received the degree of B.S. in 1883, spending the year 1884–1885 in graduate work at the Johns Hopkins. He then went to Tulane University (1885) as assistant professor of mathematics, becoming professor of applied mathematics two years later (1887). In 1889 he went to Colorado College as professor of physics, subsequently taking the chair of mathematics (1898–1918) and becoming dean of the department of engineering (1903–1918). During all these years he paid particular attention to the history of the subjects of his major interest, and in recognition of his work in this field he was called to the University of California in 1918 as professor of the history of mathematics, a unique title either in this country or abroad. This position enabled him to devote his time largely to research and writing, and the result amply justified the action of the university in creating the position, and his own decision in accepting it.

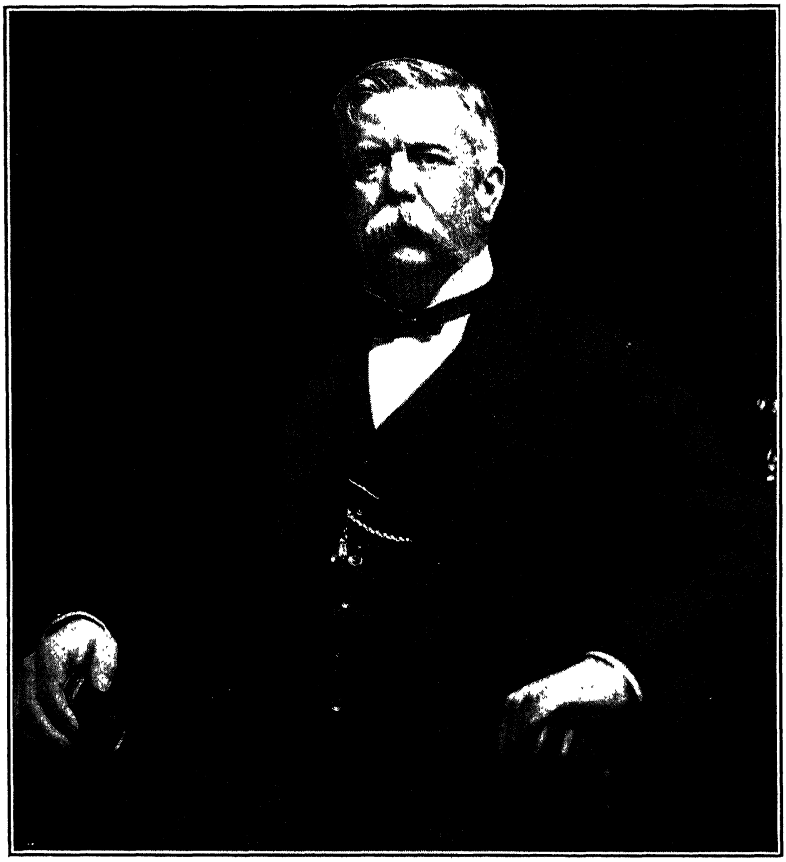
Forty years elapsed from the date of the publication of his "Teaching and History of Mathematics in the United States" (1890) to the time when death compelled him to lay aside the work which he had hoped to complete—an edition of Newton's "Principia." During these years his contributions to the history of mathematics, physics, geodesy and astronomy were numerous and of increasing value. Besides writing a large number of articles and making a brief excursion into the text-book field, he wrote the following historical works: "History of Mathematics" (1894, with a revised edition in 1919), "History of Elementary Mathematics" (1896, with a revised edition in 1917), "History of Physics" (1899), "History of the Logarithmic Slide Rule" (1909), "William Oughtred" (1916), "History of the Concepts of Limits and Fluxions in Great Britain from Newton to Woodhouse" (1919), "The Early Mathematical Sciences in North and South America" (1928), "The Chequered Career of Ferdinand Rudolph Hassler, First Superintendent of the United States Coast Survey" (1929) and the work by which he will chiefly be remembered—"The History of Mathematical Notations" (2 volumes, 1928, 1929).

His work was duly recognized by learned societies and by various colleges and universities. He was a member of the American Mathematical Society, the Mathematical Association of America, the Deutsche Mathematiker-Vereinigung, the Mathematical Association (England), the American Academy of Arts and Sciences and the American Association for the Advancement of Science, holding offices in at least two of these societies. He was honored by the degrees of Ph.D. (Tulane, 1894), LL.D. (University of California, 1912, and Colorado College, 1913) and Sc.D. (Wisconsin, 1913). As the leading historian of mathematics in this country, his loss will be deeply felt by all who have an interest in this important fie'd of learning.



DR. ARTHUR HARDEN

PROFESSOR OF BIOCHEMISTRY AT LONDON UNIVERSITY AND HEAD OF THE DEPARTMENT OF BIOCHEMISTRY AT THE LISTER INSTITUTE, WHO SHARED WITH PROFESSOR HANS VON EULER THE NOBEL PRIZE IN CHEMISTRY FOR 1929.



GEORGE WESTINGHOUSE
1846–1914

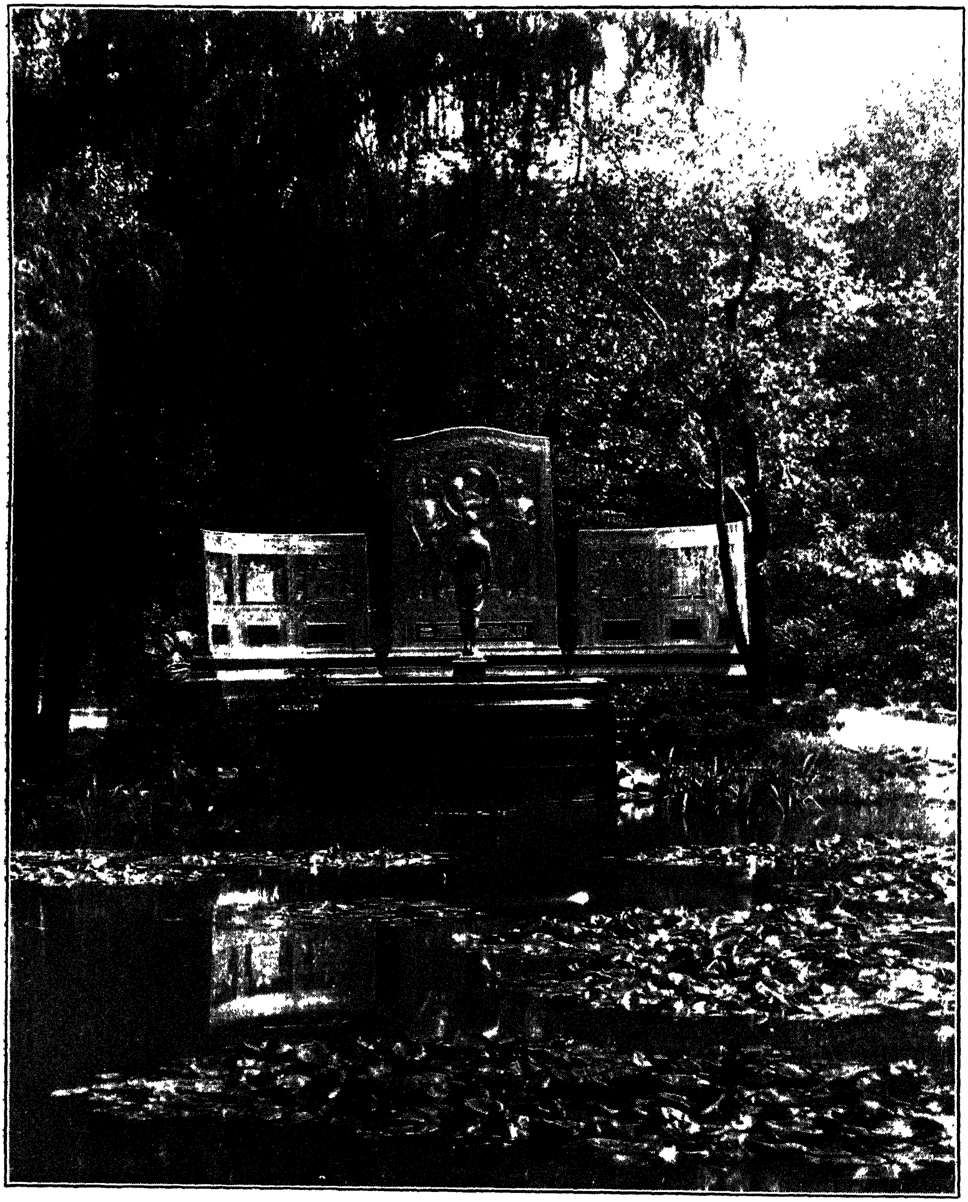
THE GEORGE WESTINGHOUSE MEMORIAL

ALTHOUGH not primarily a scientific man, for it is as a great creative and constructive genius who rendered commercially practical and beneficial to humanity the scientific developments of himself and of others that he won his greatest recognition, George Westinghouse was a pioneer in many scientific fields.

The George Westinghouse Memorial, recently erected in Schenley Park, Pittsburgh, and dedicated in October, depicts six of Mr. Westinghouse's most notable achievements, though he patented over 400 inventions.

In 1861, at the early age of 15, he invented a rotary engine; and at 20 he had produced his first railway inventions, an appliance to replace derailed railway cars and the reversible steel railway frog.

When 21, he had patented the air brake, the application of pneumatic pressure to separate brake units on each car of the train, the entire system being operated by the engineer in the locomotive cab. This invention, which made rapid rail transportation safe, revolutionized rail traffic throughout the world and promoted the development of the great



THE GEORGE WESTINGHOUSE MEMORIAL IN SCHENLEY PARK, PITTSBURGH

THE CENTRAL PART OF THE MEMORIAL

railroad facilities of to-day. But the struggle to obtain for his great invention the recognition it deserved and the final success of this fight against almost overwhelming odds shows the courage, the perseverance, the organizing ability and the unquenchable spirit of George Westinghouse. In 1868 he founded the Westinghouse Airbrake Company to manufacture and sell the airbrake.

In 1870, Mr. Westinghouse designed and built a jet steam turbine. In the same year he traveled to Europe to begin a ten-year crusade in England and on the continent to establish his railway safety appliances. In 1873 he designed and built the first automatic central telephone exchange, which was, unfortunately, a score or more years ahead of the times. In 1879 he invented the principle of modern railway signalling, the pneumatic system of interlocking signals, operated by compressed air.

His mind was not entirely wrapped up in blue prints and patents; at this period of his life he delved into a social experiment—possibly the first effort in America to better the workman's living condition—by instituting the Saturday half holiday.

The year 1880 saw him terminate his inventive activities for a brief period and return to organization of industries. In that year the Westinghouse Machine Company (later reorganized as the present Westinghouse Electric and Manufacturing Company) was founded in Pittsburgh for the manufacture of high

speed engines designed by H. H. Westinghouse, George's brother. The next year the Union Switch and Signal Company, of Pittsburgh, was formed for the production of the pneumatic switch and signal.

The almost unlimited supply of natural gas located in the hilly country of Western Pennsylvania was seen by the alert inventor to be of potential value to industries and homes if it could be piped to consumers. With his customary, lightning-like thoroughness it was but a short time after finding a use for gas that he had perfected a complete system for transmitting gas through pipes, invented a meter for measuring consumption and organized companies to distribute this gas.

The year 1885 marks a new era in the life of Westinghouse; in that year he began investigating the little-explored realm of electrical application, and decided that alternating current, then far from the practical tool it is to-day, would provide the solution for the problem of the efficient and flexible transmission of power. He purchased the transformer patents held by the Englishmen, Gaulard and Gibbs; and in 1886 he organized the Westinghouse Electric Company for the manufacture of electric lighting apparatus. He then engaged Nicola Tesla, a young European scientist of great talent, who, in collaboration with Westinghouse, developed the alternating current induction motor.

As the champion of alternating current, Mr. Westinghouse met hostile and stubborn opposition, but his indomitable character finally won recognition of the advantages of this type of current. Lighting the Chicago World's Fair, the construction of the world's first hydro-electric plant at Niagara Falls, the design of the early street cars and the production of the first electric locomotive stand as milestones along the path he trod as he achieved success in the electrical industry.

To his well-filled record of achievements were added the first commercial steam turbines in 1898; the erection of the British Westinghouse Company at Manchester, England, and the application of the steam turbine to steamships, in collaboration with Rear Admiral George Melville, U. S. N., and John H. MacAlpine, inventor, in 1904. He began development of the air spring for automobiles in 1910; made a successful installation of reduction gears in the United States collier, *Neptune;* and in the year of his death, 1914, he had the final honor of having his reduction gears selected by the United States Navy for installation in two battleships. His machinery was chosen in preference to any other offered.

In 1914 death cut short further research and further achievements of one of the foremost contributors to America's industrial supremacy. The world knew him best as a remarkable industrialist and a developer of electricity, but, in addition, admired and respected him as an engineer, inventor and man of science.

THE SCIENTIFIC MONTHLY

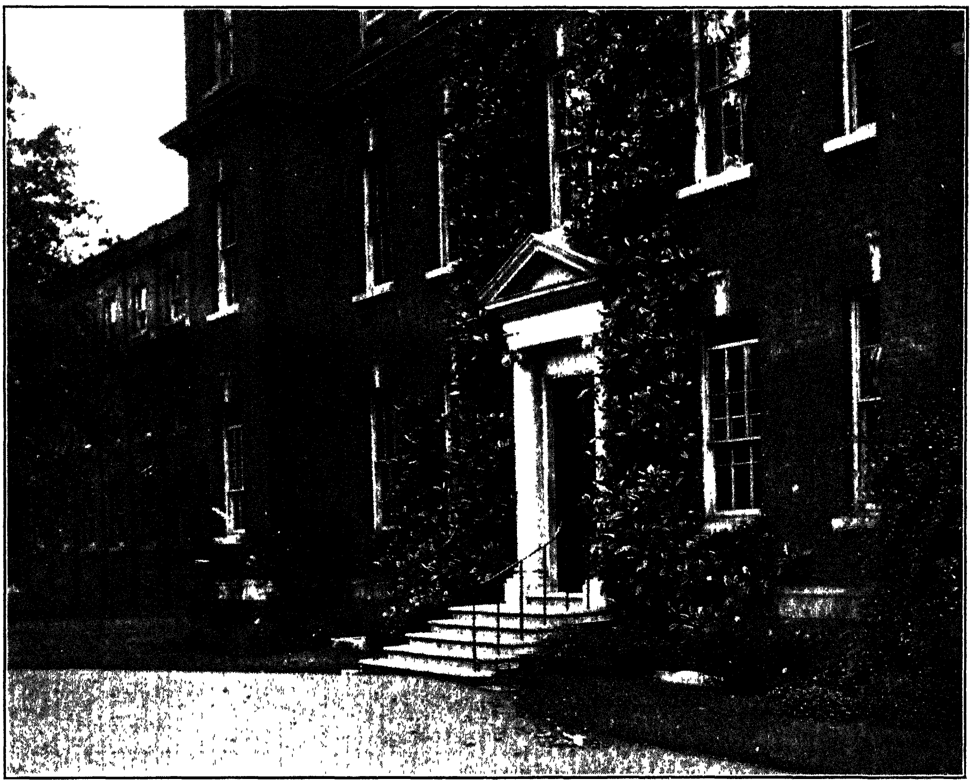
DECEMBER, 1930

A BOTANICAL TRIP TO SOUTH AND EAST AFRICA

By Dr. A. S. HITCHCOCK

BUREAU OF PLANT INDUSTRY, UNITED STATES DEPARTMENT OF AGRICULTURE

THE British Association for the Advancement of Science met in South Africa last summer (1929) in cooperation with the South African Association for the Advancement of Science. The writer was invited to attend the meeting



THE HERBARIUM OF THE ROYAL BOTANIC GARDEN AT KEW

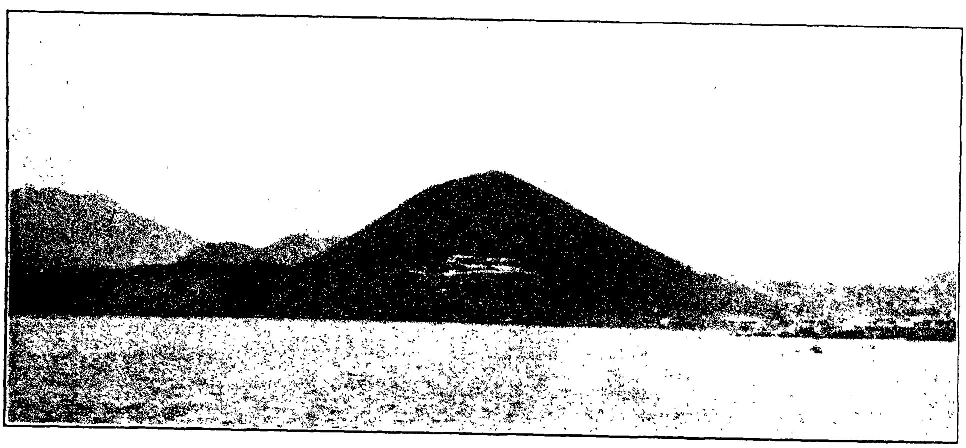
which was held at Capetown, from July 22 to 27, and at Johannesburg, from July 30 to August 5.

Leaving America early in June, I went to London, taking from there the *Llandovery Castle* of the Union Castle line. About ten days were spent in London studying types of grasses at Kew. On board the *Llandovery Castle* were about 160 scientists bound for the scientific meetings. Other boats brought their quotas. There were in attendance at the meetings only about a dozen from the United States and Canada and a sprinkling from the Continent of Europe.

THE GREAT DRAGON TREE

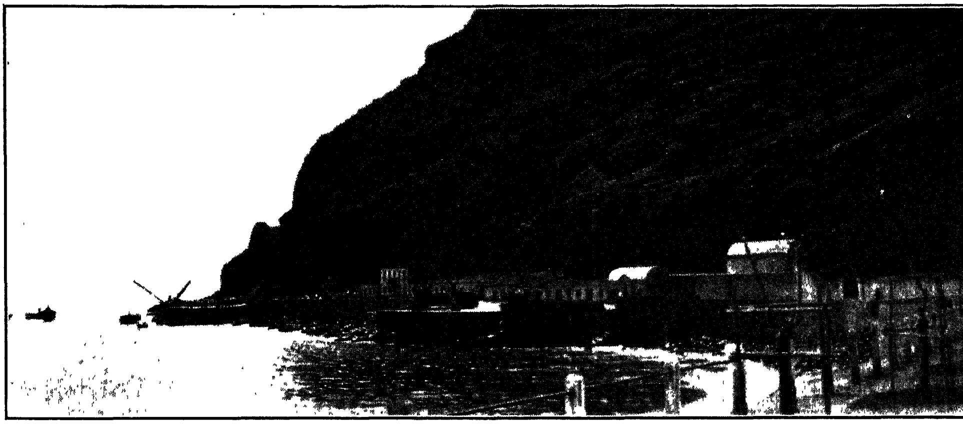
(*Dracaena draco*) ON TENERIFFE. DR. RENDLE, OF THE MUSEUM OF NATURAL HISTORY AT SOUTH KENSINGTON, HAS JUST TAKEN A PICTURE OF THE SAME TREE.

The *Llandovery Castle* called at the island of Teneriffe where passengers landed for a few hours, taking drives over the hills and going through some of the parks of Santa Cruz. The famous peak of Teneriffe (12,152 feet) was hidden from view by a covering of clouds. Botanists were interested in a large specimen of the dragon tree (*Dracaena draco*) said to be very old. Another prominent feature of the landscape was a succulent spiny species of Euphorbia (*E. canariensis*) which resembled a cactus. The plants are tree-like with a single trunk, but the branching resembles that of a candelabra as in many of our southwestern and Mexican species of cactus.



THE ISLAND OF ASCENSION

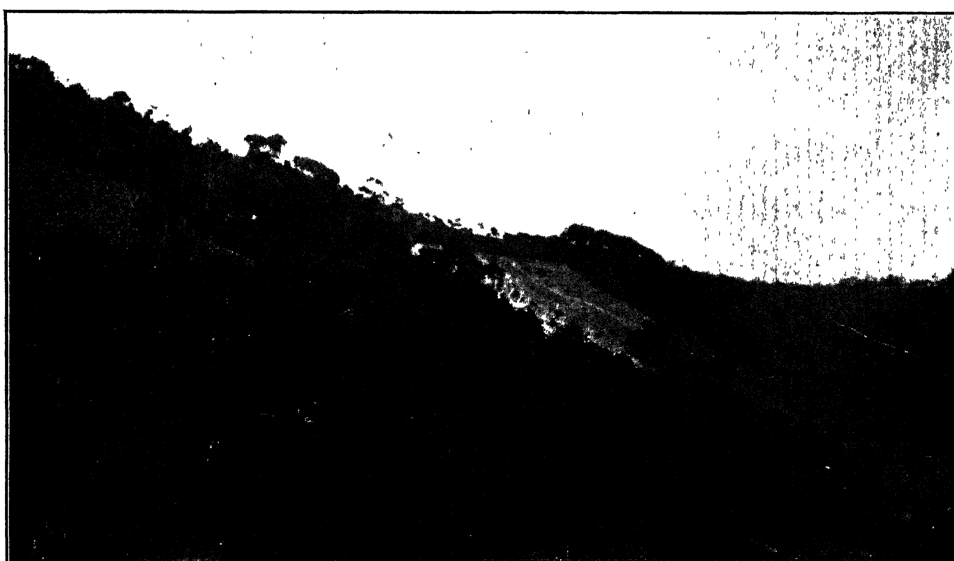
WITH THE CABLE STATION, TAKEN FROM THE STEAMER AT ANCHOR.



THE LANDING PLACE ON THE ISLAND OF ST. HELENA

THE COAST IS PRECIPITOUS AND THE WHOLE ISLAND IS MOUNTAINOUS.

The weather now began to be warm but was uncomfortable for only two or three days. We were in sight of land as we rounded the westernmost coast of Africa. The next land sighted was the small island of Ascension, which lies about eight degrees south of the equator. The island has an area of only 38 square miles, but the central part rises to a height of 2,820 feet. We were unable to land as the steamer was anchored a considerable distance out and the facilities for landing were too meager to accommodate so many passengers. The island is quite barren although it is said that there is vegetation near the summit



THE INTERIOR OF ST. HELENA

TERRACED FIELDS OF NEW ZEALAND FLAX (*Phormium tenax*) IN THE MIDDLE DISTANCE. A COARSE FIBER IS OBTAINED FROM THE LEAVES. NEW ZEALAND FLAX IS THE CHIEF EXPORT OF THE ISLAND.

THE GRAVE OF NAPOLEON

ON THE ISLAND OF ST. HELENA. THIS PLOT OF GROUND IS FRENCH TERRITORY THOUGH THE ISLAND BELONGS TO GREAT BRITAIN. THE BONES OF NAPOLEON HAVE BEEN REMOVED TO PARIS.

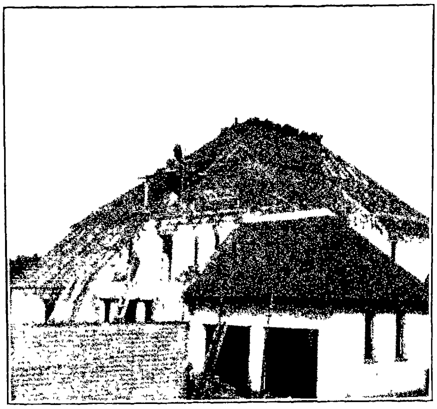
BOTANISTS ON AN EXCURSION
THROUGH THE CAPE PENINSULA SOUTH OF CAPETOWN.

because of the clouds and mists there. Great Britain maintains a cable station on the island.

Seven hundred miles further to the southeast, and still within the tropics, lies the beautiful island of St. Helena, known to Americans chiefly as the home of Napoleon from 1816 till his death in 1821. The rugged mountainous island has an area of 47 square miles, the highest point being 2,700 feet above the sea. Several hours were spent upon the island by the passengers, many of whom visited Longwood, the residence of Napoleon. Nearby is the grave of Napoleon, whose body, however, has been removed to Paris. The rainfall is sufficient to give a fairly ample flora and the botanists were very busy. The chief export crop of St. Helena is New Zealand flax (*Phormium tenax*), the leaves of which produce a coarse fiber useful for cordage and bagging.

The weather had been cool since leaving the equator and became much cooler as we approached Capetown.

TUSSOCKS OF A SPECIES OF THE FAMILY RESTIONACEAE
ALLIED TO THE SEDGES AND GRASSES. THIS FAMILY IS WELL REPRESENTED IN SOUTH AFRICA.



A NEW BUILDING BEING THATCHED WITH THE STEMS OF RESTIONACEAE. THE LOWER ROOFS SHOW THE THATCHING COMPLETED. THESE PLANTS ARE COMMONLY USED FOR THATCHING IN THE CAPE REGION.

The arrangements for the reception of visiting scientists were unusually good. According to a plan worked out in advance there was a host for each guest. My host, an American in residence, looked after my welfare from the time the steamer arrived until I left for Johannesburg. The host system was used at the latter city also. I have never attended a scientific meeting anywhere in the world where guests were so delightfully entertained and where the plans for entertainment were carried through with such perfection and punctuality.

THE BOLUS HERBARIUM

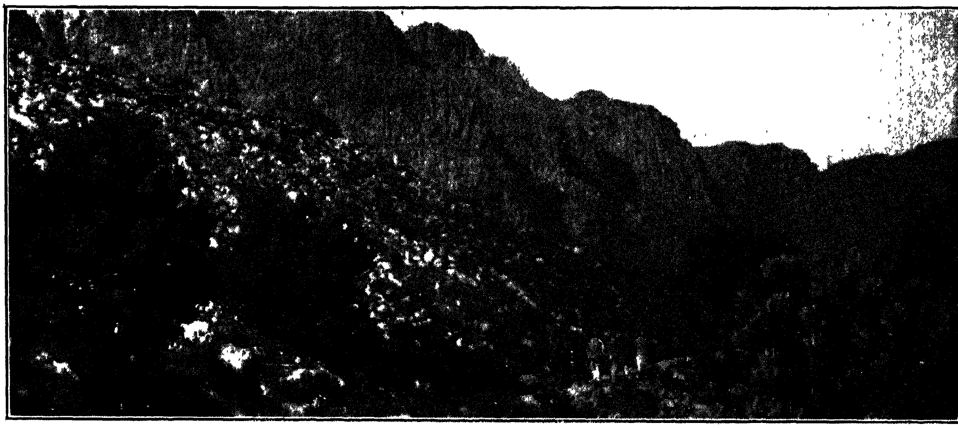
IN THE KIRSTENBOSCH BOTANIC GARDEN, CAPETOWN. THE BOLUS HERBARIUM IS ONE OF THE IMPORTANT COLLECTIONS OF PLANTS IN SOUTH AFRICA.

The sessions of the Botanical Section of the association were well attended, and there was opportunity to meet nearly all the South African botanists. The sessions of the association were held in the fine large buildings of the University of Capetown. The writer read by invitation a paper on "The Relation of Grasses to Man."

The National Botanic Gardens at Kirstenbosch were of great interest to visiting botanists. The garden is near Capetown, the upper part running up on the slopes of Table Mountain to the top (3,500 feet). A large part of the garden is given over to the preservation of the indigenous vegetation, which has great botanical interest because the flora of the Cape region is peculiar and striking, and for the most part different from that of any other part of the world. Within the garden is the Bolus Herbarium, containing a large collection of South African plants.

A SHRUB OF THE FAMILY PROTEACEAE (*Protea grandiflora*), ONE OF THE PECULIAR FAMILIES CHARACTERISTIC OF THE CAPE REGION.

There is an important herbarium also at the South African Museum, adjoining the Municipal Botanic Gardens of Capetown.

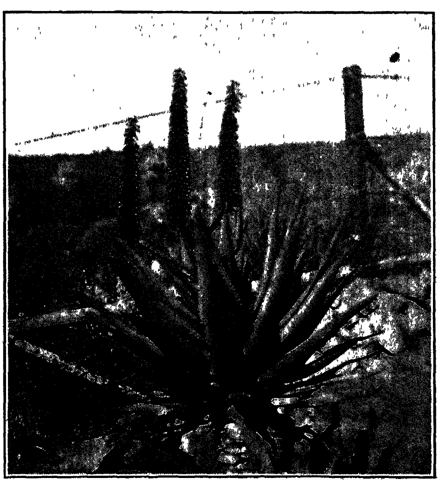


PROTEACEAE (*LEUCOSPERMUM LEPTOCARPUM*)
ON THE SLOPES OF TABLE MOUNTAIN NEAR CAPETOWN.

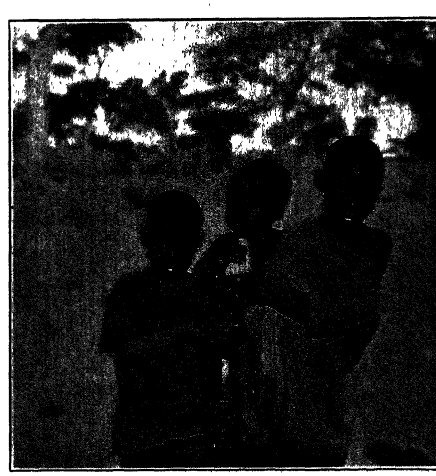
Excursions for botanists to the surrounding regions furnished an opportunity for examining the wonderfully rich flora. It is said that the Cape Peninsula supports a flora of about 2,500 species of flowering plants. The Cape Peninsula is a narrow tongue of land projecting southward from Capetown for about 30 miles, the central core being Table Mountain and its extension to the Cape of Good Hope at the southern extremity. The family Proteaceae forms a conspicuous element of the flora. There are large numbers of monocotyledonous plants with bulbs and corms. Succulents abound, the genus Mesembryanthemum and its allies being particularly noticeable.

Although the time of our visit (August) was the winter season a large number of plants were found in bloom. The annual rainfall at Capetown is about 25 inches. Frost is unknown in the city but occurs at higher altitudes.

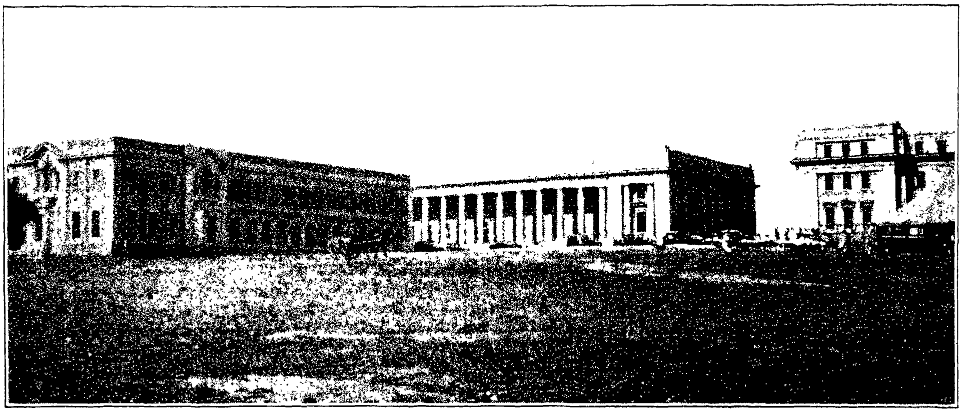
The sessions of the second week of the



A SUCCULENT (*ALOË FEROX*)
IN THE KAROO GARDEN AT WHITE HILLS. THIS IS A BRANCH OF THE MAIN GARDEN AT CAPETOWN.



NATIVE CHILDREN AT A RAILWAY STATION



A FEW OF THE FINE NEW BUILDINGS

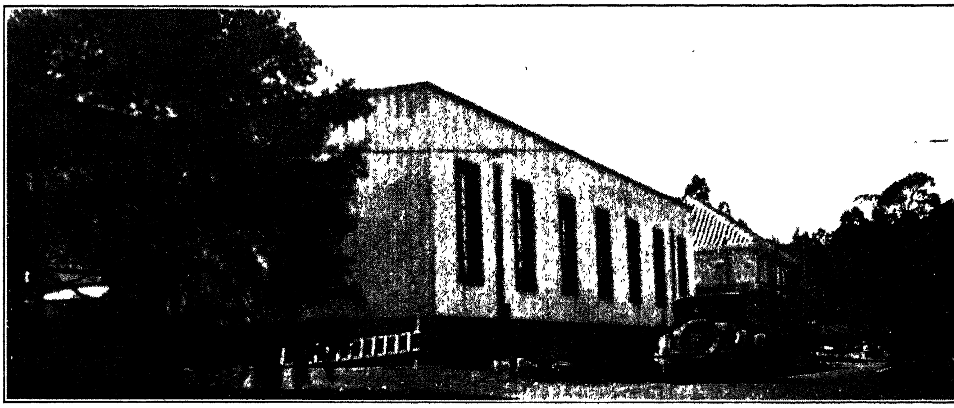
OF THE WITWATERSRAND UNIVERSITY AT JOHANNESBURG. THE BOTANICAL DEPARTMENT IS IN THE BUILDING TO THE LEFT.

association were held at Johannesburg. This is the largest city in South Africa, the population being about 175,000 white and 150,000 colored. It lies on a plateau at an elevation of 6,000 feet about 1,000 miles north and east of Capetown. Johannesburg is a modern metropolis reminding an American of his middle western cities. The Witwatersrand University has several large and imposing buildings. The botanical department is well equipped and has a good herbarium. In this region I observed for the first time a beautiful lawn grass (*Cynodon transvaalensis*) allied to our Bermuda grass but with a much finer texture and a darker green color. My host and hostess at Johannesburg, both Americans, looked after my welfare in that city in the same efficient and sympathetic manner that characterized the oversight of guests during their entire stay in South Africa.

About 40 miles north of Johannesburg lies Pretoria, a city of about 100,000 inhabitants including the colored

A FINE LAWN OF TRANSVAAL GRASS

(*Cynodon transvaalensis*) IN FRONT OF THE HOUSE OF MY HOST, MR. WARTENWEILER, AT JOHANNESBURG. THE GRASS IS ALLIED TO OUR BERMUDA GRASS BUT IS MUCH FINER IN TEXTURE.



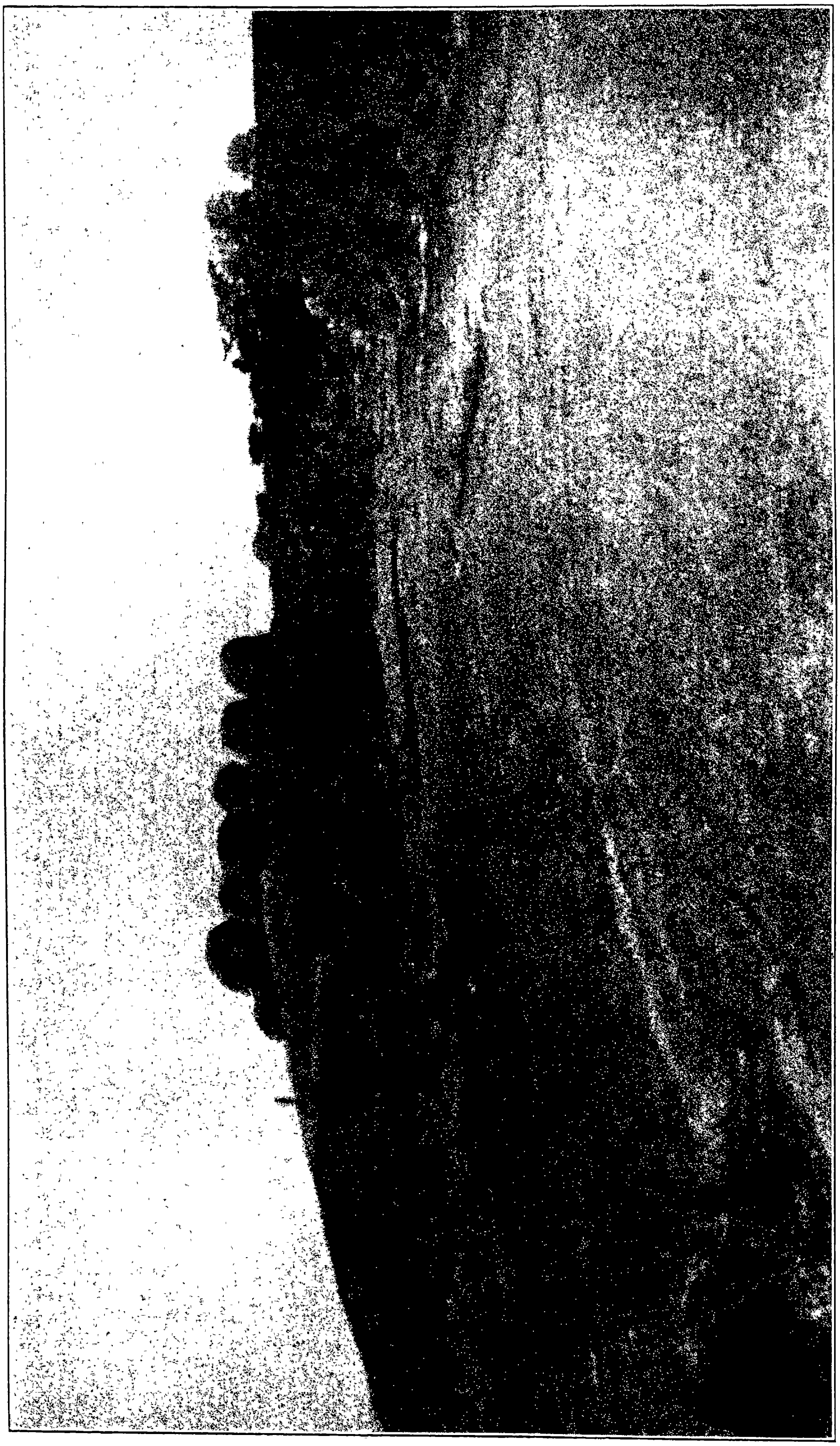
THE HERBARIUM
OF THE BUREAU OF PLANT INDUSTRY AT PRETORIA (THE NATIONAL HERBARIUM).

population. This is the administrative capital of the Union of South Africa. Here is the National Department of Agriculture, one division of which, the Division of Plant Industry, includes the botanical investigations of the government. The National Herbarium contains a large collection of African plants. At the Experiment Station there is a good collection of native forage grasses grown in plots.

Considering the age and development of the Union of South Africa, the progress made in science and education is striking. The buildings of the universities and museums are large, modern and of fine appearance. The botanical departments are well equipped and well staffed. There are several herbaria, the largest of which are the National Herbarium, the Bolus Herbarium and the Herbarium of the South African Museum at Capetown.

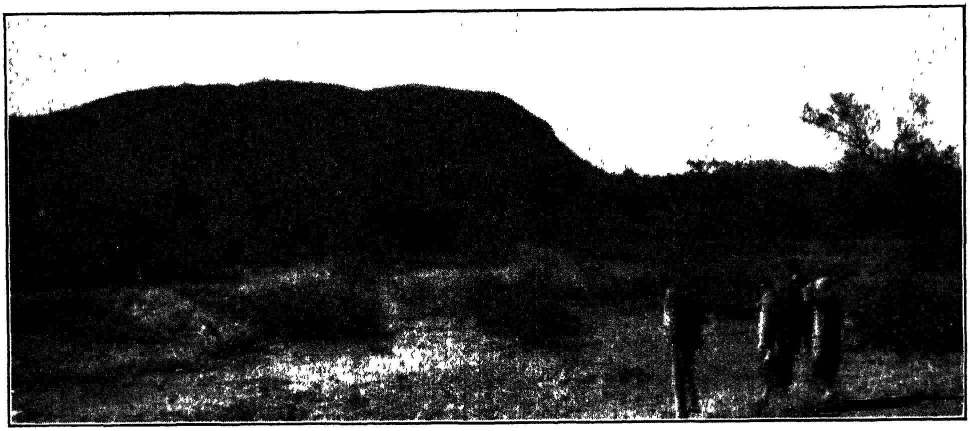
The visiting scientists were offered the

THE TRAIN
ON WHICH ONE OF THE EXCURSION PARTIES SPENT 12 DAYS FROM JOHANNESBURG TO VICTORIA FALLS AND BEIRA.



MOTOPO HILLS NEAR BULOWAYO

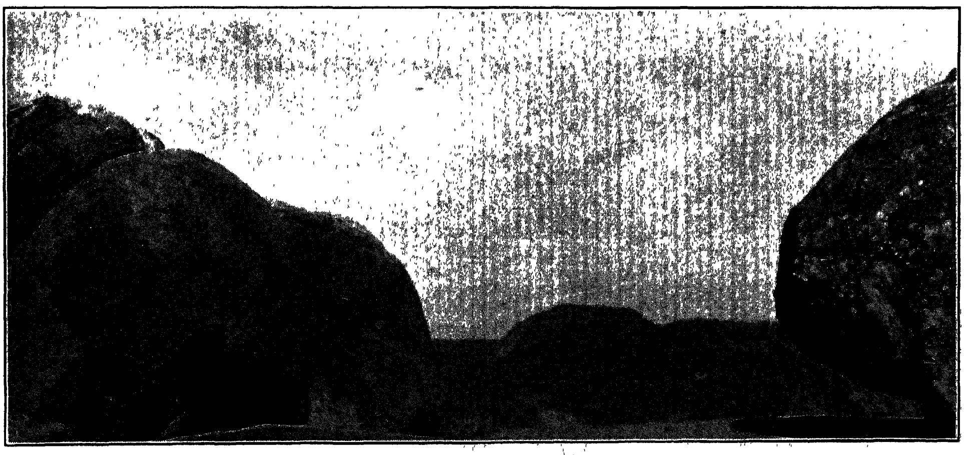
THE BOULDERS ARE ON THE HIGHEST POINT, "WORLD'S VIEW," OVERLOOKING THE COUNTRY FOR MILES AROUND. RHODES'S GRAVE LIES AMONG THE BOULDERS.



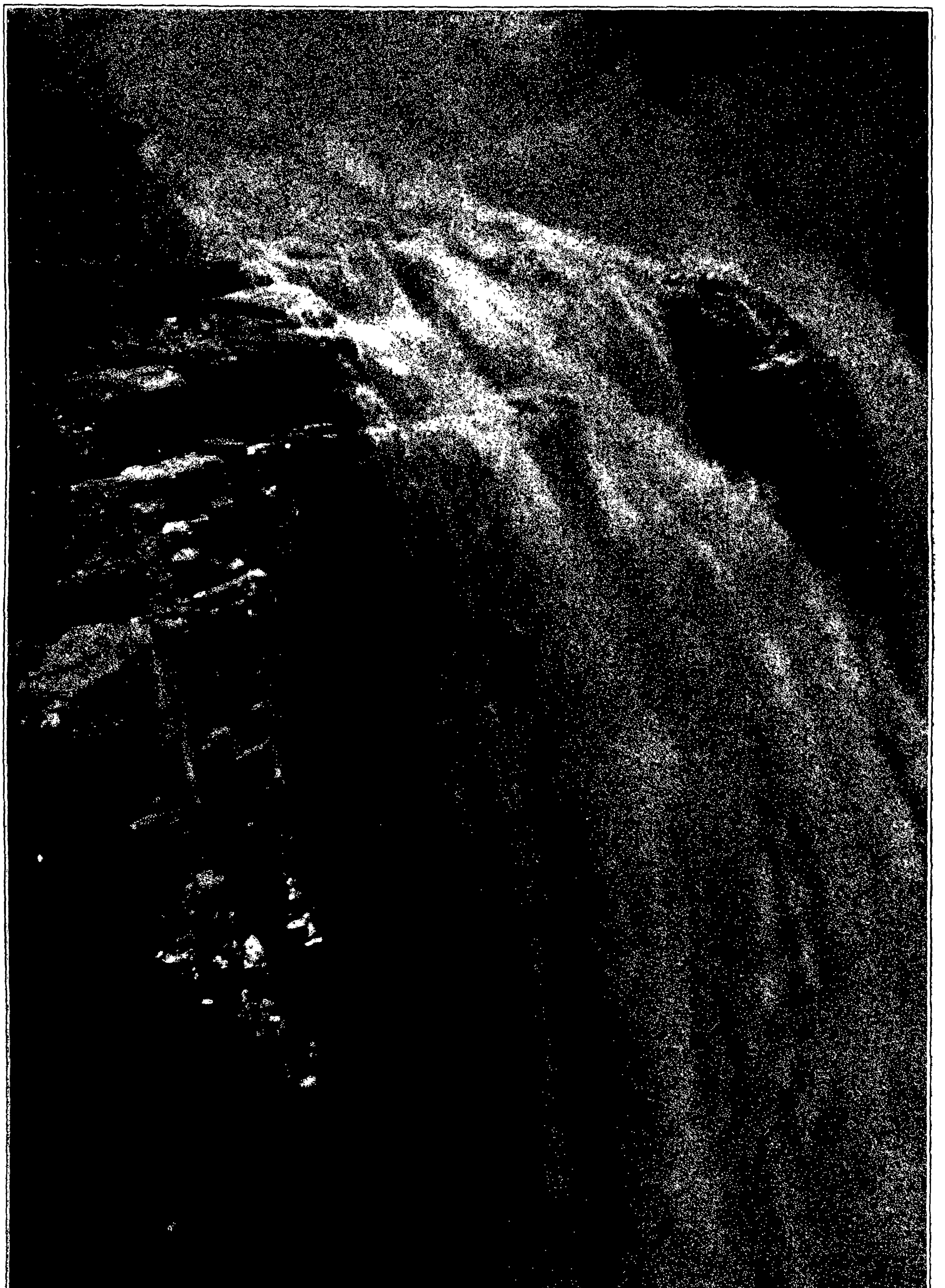
CHAPARRAL IN SOUTHERN RHODESIA
THIS ARID REGION REMINDS ONE OF PARTS OF OUR SOUTHWEST.

privilege of participating in several excursions. Many botanists, including myself, left Capetown Saturday night by special train to examine the flora of the Karoo, an arid region between Capetown and Johannesburg. Two days were spent in the Karoo under the leadership of Professor Compton, director of the National Botanic Gardens. The Karoo formation includes a large part of the interior of the Cape Province. It is an arid plateau, mostly 1,500 to 3,000 feet in altitude with a rainfall usually under 12 inches. The vegetation is rich in succulents.

At Whitehill, a station on the railroad through the Karoo, is the Karoo Garden, a branch of the National Botanic Gardens at Kirstenbosch (Capetown). This garden is a natural preserve of 40 acres at an altitude of 3,000 feet, with an annual rainfall of about six inches. The garden is rich in native succulents. The visiting botanists spent several



THE GRAVE OF CECIL RHODES
A PROMINENT FIGURE IN SOUTH AFRICA A FEW YEARS AGO. THE TOP OF THE GRAVE IS SEEN AT THE BASE AMONG THE BOULDERS.



A SMALL PART OF THE VICTORIA FALLS

THE FALLS ARE 420 FEET HIGH AND 6,000 FEET WIDE.

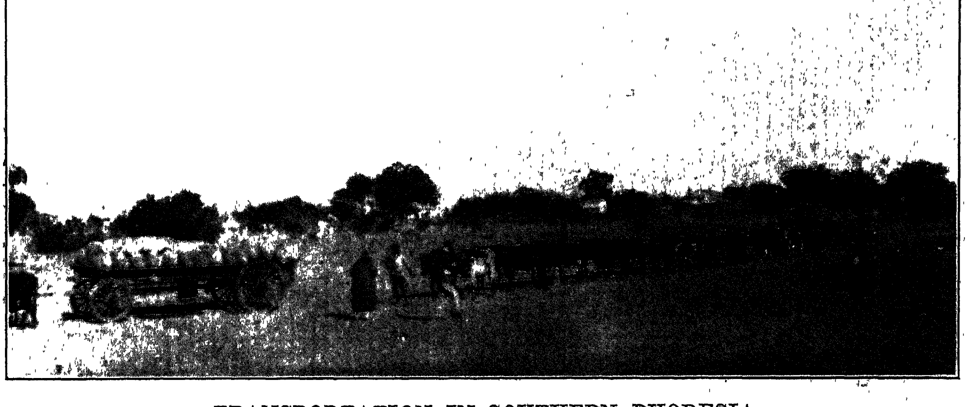
NATIVE HUTS NEAR VICTORIA FALLS

hours studying the strange and interesting flora. Here were plants related to Mesembryanthemum consisting of two hard succulent leaves, the whole resembling in form and color the small globular stones among which they grew.

On the way to Johannesburg the party stopped at Kimberley, where the diamond mines were visited. We had the unusual opportunity of viewing at the offices great piles of diamonds worth hundreds of thousands of dollars.

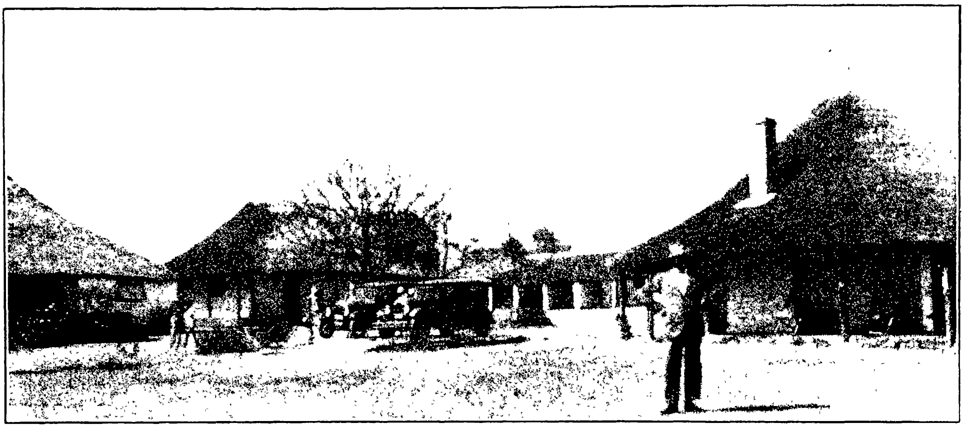
After the close of the scientific meetings I joined an excursion by special train to Victoria Falls. For two weeks we lived on the train, which was provided with sleeping accommodations, dining car and baggage cars where the heavy baggage was always accessible. The management of this excursion was all that could be desired.

At Bulowayo (Southern Rhodesia) we went by motor to the Motopo Hills, a park with much beautiful natural scenery. The highest point, World's View, is a bare rounded hill, from which one obtains a view over the surrounding country for many miles in all directions.



TRANSPORTATION IN SOUTHERN RHODESIA

TEAMS OF 8 AND 9 YOKE OF OXEN WERE COMMONLY USED BY THE BOERS IN THE EARLY DAYS BEFORE THE ADVENT OF THE MODERN MOTOR TRUCK AND ARE STILL TO BE SEEN IN REMOTE REGIONS. THIS PICTURE WAS TAKEN AT FORT VICTORIA.



THE HOTEL AT ZIMBABWE

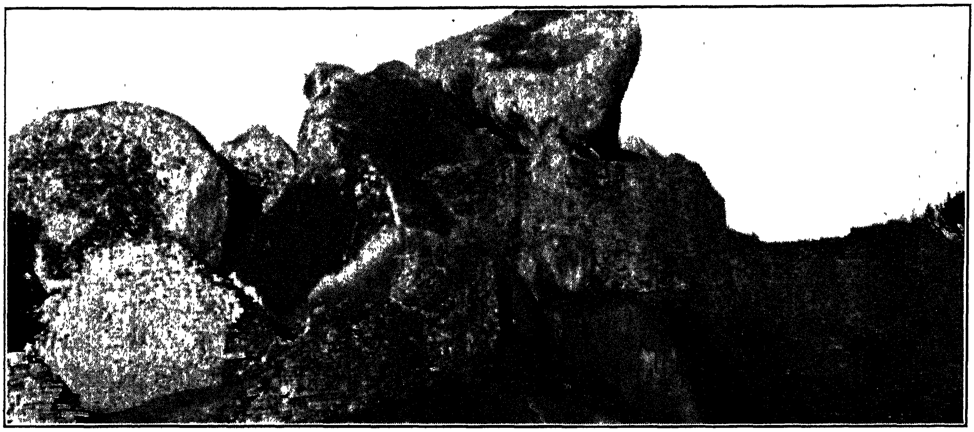
12 MILES SOUTH OF FORT VICTORIA. THE BUILDINGS ARE IN IMITATION OF THE NATIVE HUTS. THE ZIMBABWE RUINS ARE NEARBY.

The hill is topped by several large boulders among which is set the grave of Cecil Rhodes and his comrade Jameson. The archeologists were interested in a cave containing Bushman paintings.

Two days were spent at Victoria Falls in the Zambesi River. These remarkable falls are one of the wonders of the world. They are 420 feet high and about 6,000 feet wide. The peculiar contour is such that it is impossible, except from the air, to get the falls in a single view. The vast amount of spray also interferes. For these reasons the Niagara Falls, with which the Victoria Falls are often compared, are more impressive because of the good view and the regularly large volume of water passing over. The seasonal variation of the amount of water passing over the Victoria Falls is great. During high

EUPHORBIAS NEAR ZIMBABWE RUINS

IN HABIT THESE PLANTS RESEMBLE CACTUSES, THOUGH BELONGING TO AN ENTIRELY DIFFERENT FAMILY.



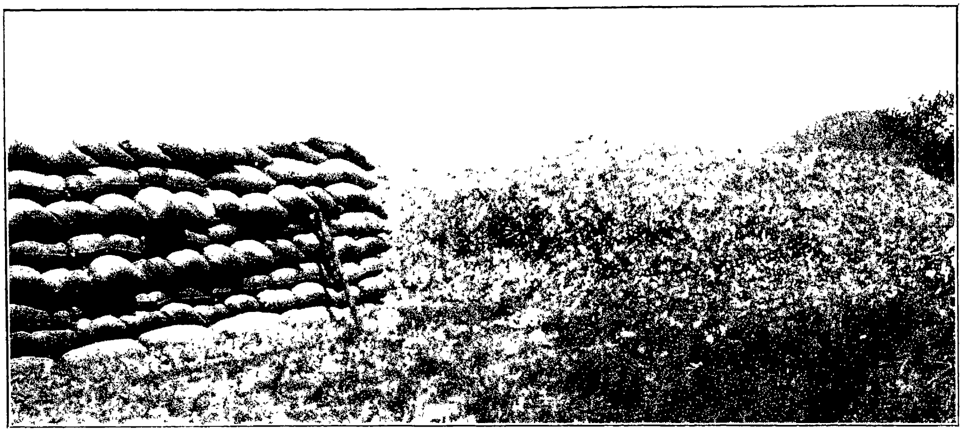
THE ACROPOLIS

A PREHISTORIC FORTIFICATION THAT IS ON A HILL NEAR THE OTHER RUINS AT ZIMBABWE. THE GREAT BOULDERS HAVE BEEN REINFORCED BY ARTIFICIAL WALLS.

water the spray fills the canyon and little can be seen. The peculiarity of the Victoria Falls is the position and contour of the canyon. The river flows through a great lava bed and the general level of the country is the same above and below the falls. The chasm into which pours the water from the falls is at right angles to the flow of the river, hence the falls appear to plunge toward a solid wall in front. Through this wall, at a narrow deep gorge, flows the entire river. It seems almost unbelievable that so much water can pass through such a narrow gorge. The railroad bridge that spans the canyon just below this gorge gives the observer a good view in both directions. The canyon below the bridge makes two hairpin turns and then extends down the river

A MAIZE FIELD NEAR FORT VICTORIA

MAIZE OR CORN, KNOWN IN SOUTH AFRICA AS MEALIES, IS EXTENSIVELY CULTIVATED, ESPECIALLY IN TRANSVAAL AND RHODESIA. THE FIELD SHOWS THE WINTER CONDITION AFTER THE EARS HAVE BEEN GATHERED.



SACKS OF "MEALIES" (MAIZE) READY FOR SHIPMENT

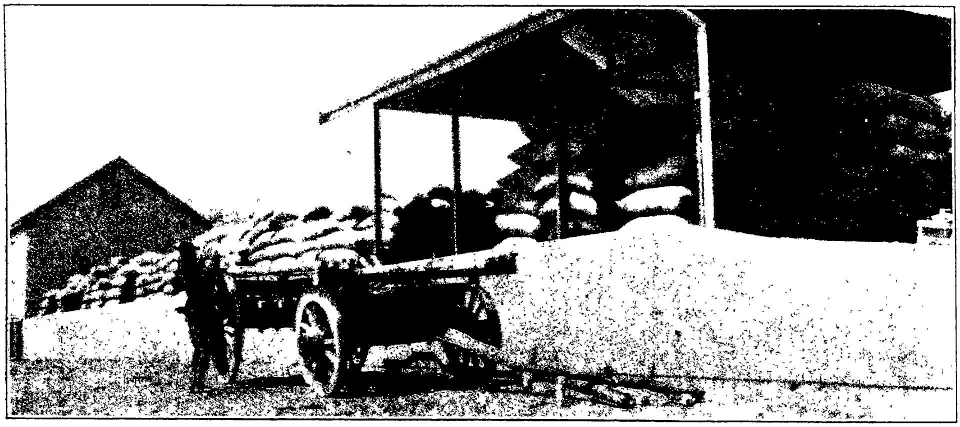
NEAR FORT VICTORIA (FARM OF MR. HALLIDAY). THE EARS ARE HUSKED BY MACHINERY; THE SHREDDED HUSKS ARE IN THE BACKGROUND.

for 40 miles. Victoria Falls were discovered and made known to the world by David Livingstone in 1855.

In the vicinity of Victoria Falls we saw our first baobab tree (*Adansonia digitata*). These curious and somewhat ungainly trees were bare of leaves at the time of our visit. They have a trunk entirely out of proportion to the branches. The girth may be as much as 75 or even 100 feet while the height may be 50 or 60 feet. These trees were seen again in East Africa, and the species extends across Africa to Senegal.

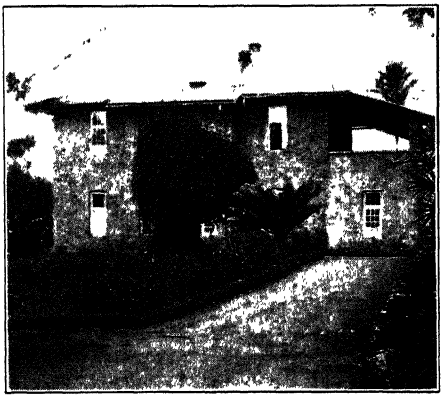
Our next stop of importance was at the Zimbabwe ruins 12 miles south of Fort Victoria, the nearest railroad station.

The buildings were evidently erected for the protection of those engaged in the gold industry. From the discovery of crucibles and other implements, it is obvious that ore was smelted within the walls. It seems probable that Great Zimbabwe was the chief inland stronghold of



"MEALIES" (MAIZE) IN SACKS

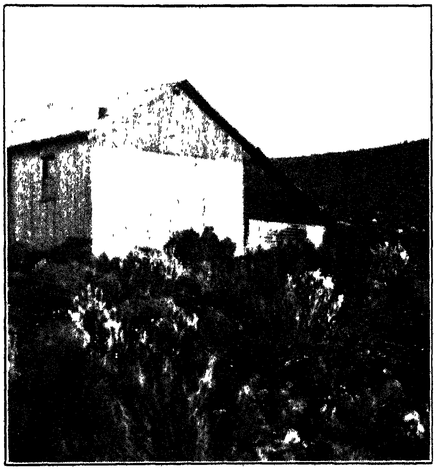
AT A RAILWAY STATION READY FOR SHIPMENT.



THE HOME OF THE DIRECTOR
OF THE AMANI AGRICULTURAL INSTITUTE, THE CENTER OF SCIENTIFIC RESEARCH IN TANGANYIKA (FORMERLY GERMAN EAST AFRICA).

those who came in search of the precious metal.[1]

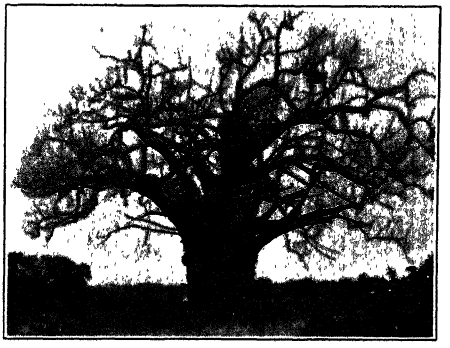
The archeologists were greatly interested in these ruins, some of which were in a good state of preservation. The age of the ruins is not known but they are thought to date within the Christian era.



PETER'S HUT
(ALT. 11,500 FT.) THE SECOND RESTHOUSE ON THE TRAIL UP MT. KILIMANJARO. THIS IS IN THE ALPINE REGION.

[1] "The South and East African Year Book and Guide for 1929," page 458.

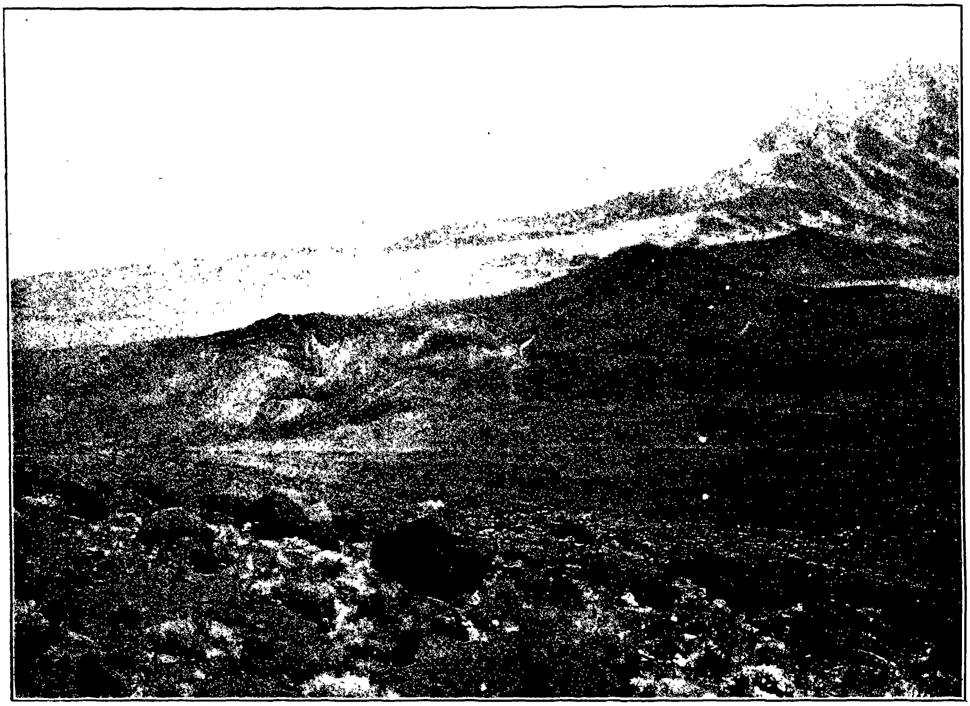
A large farm near Fort Victoria was visited by many of our party. This farm gives an example of the modern methods of agriculture practiced in Southern Rhodesia. Agricultural machinery is freely used, and it was noted that this came mostly from America. We were told that 95 per cent. of the automobiles in South Africa were of American make. The conditions in the rural districts of South Africa are similar to those found in rural America. Heavy powerful machines are needed; those coming from England are too light.



BAOBAB TREE (*ADANSONIA DIGITATA*)
NEAR MOSHI AT THE BASE OF MT. KILIMANJARO. THE NATIVES HAVE PLACED IN THE BRANCHES SMALL HOLLOW LOGS FOR BEEHIVES.

It was interesting to note that four of the most important food plants cultivated in Rhodesia and Transvaal are of American origin: maize (called mealies in South Africa), sweet potato, white potato and casava. The last is a staple food plant of Brazil and other parts of tropical America. The part used is the fleshy roots rich in starch. It comes into the American market as tapioca.

The excursion ended at Beira in Portuguese East Africa where we embarked on a steamer for the north. Some of the party remained on the steamer till it reached London. Others

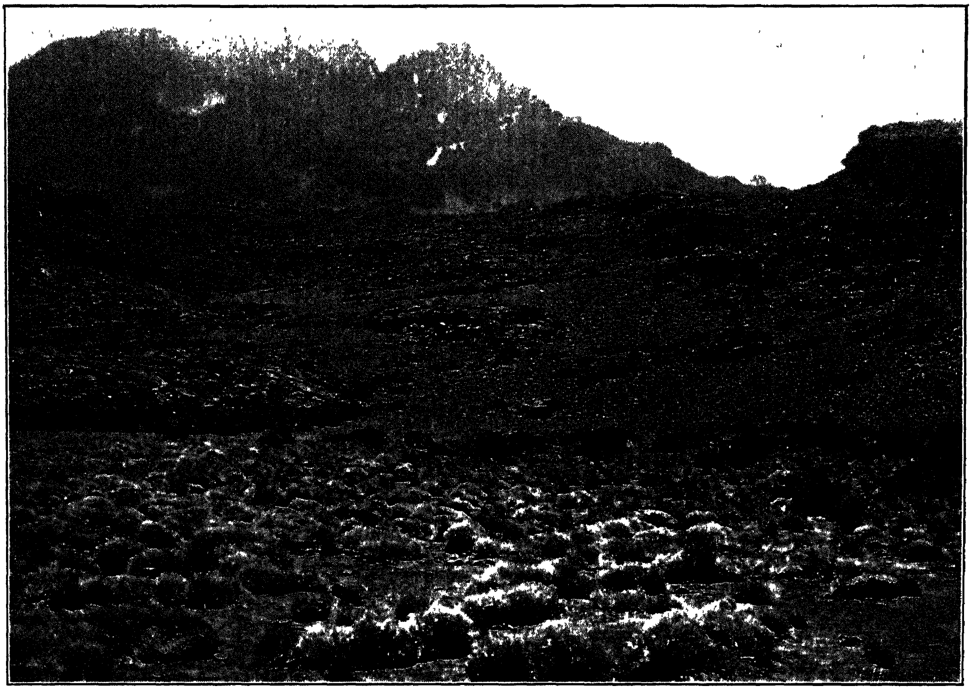


KIBO PEAK OF MT. KILIMANJARO

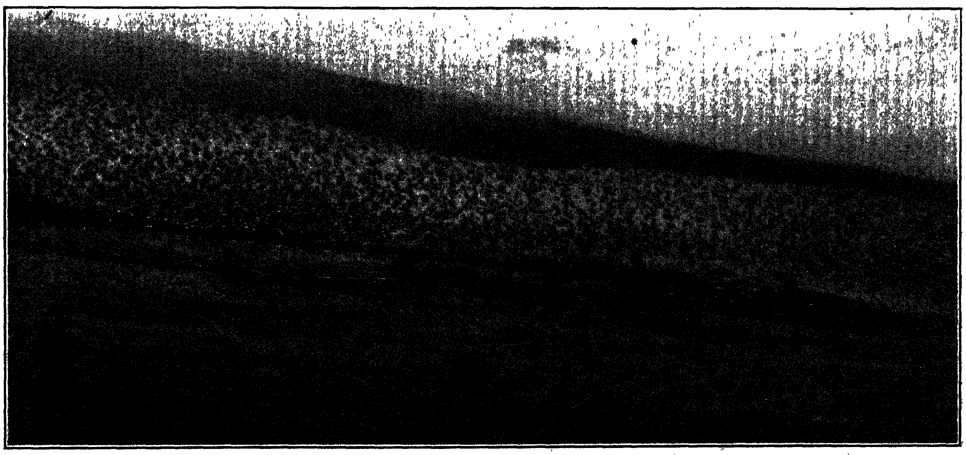
FROM ABOUT 14,000 FT., THE LIMIT OF VEGETATION AT THIS POINT.

TRAIL UP MT. KILIMANJARO

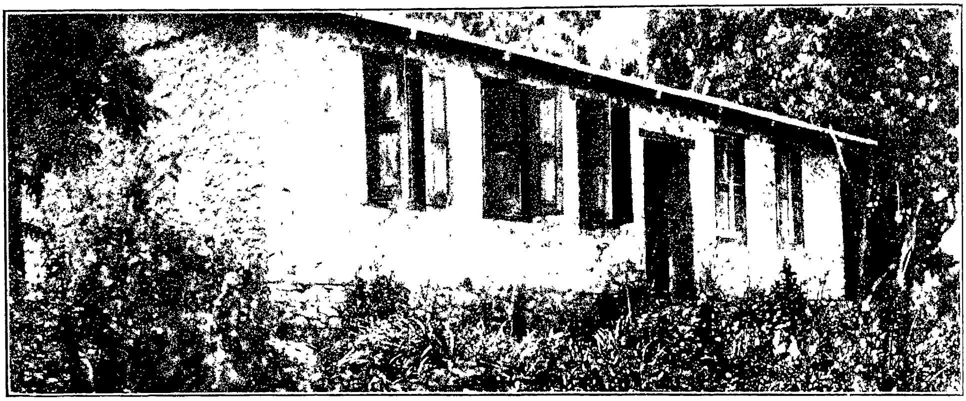
PASSING THROUGH THE SCRUB ZONE ABOVE THE FOREST. THE PORTERS ARE RESTING.



MAWENZI, THE EASTERN PEAK OF MT. KILIMANJARO
(ALT. ABOUT 17,000 FT.), TAKEN FROM 14,000 FT. ELEVATION.



ALPINE REGION ON MT. KILIMANJARO
ABOVE PETER'S HUT, ALTITUDE ABOUT 12,000 FEET. A BOG WITH SCATTERING PLANTS OF *Senecio Johnstonii.*



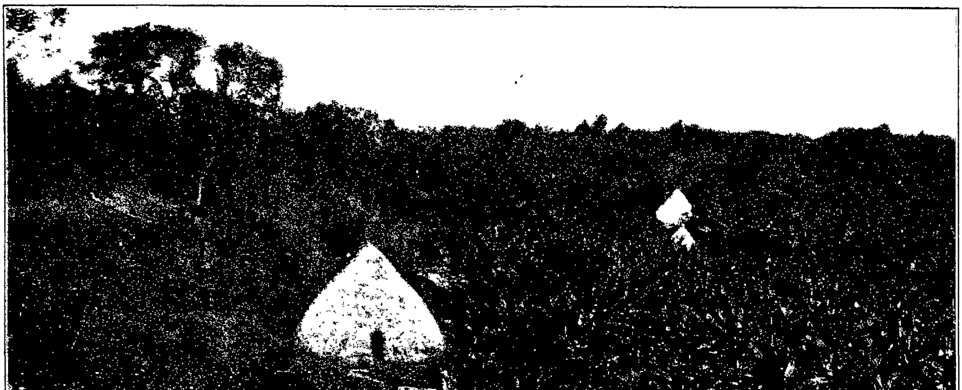
BISMARK HUT

(ALT. 8,500 FT.) THE FIRST RESTHOUSE ON THE TRAIL UP MT. KILIMANJARO NEAR THE UPPER LIMIT OF THE RAIN FOREST.

disembarked at Mombasa and went up to Nairobi. A few of us, including Mr. Cotton, keeper of the Kew Herbarium, landed at Tanga. On the way we stopped a short time at Dar-es-Salaam and Zanzibar. Dar-es-Salaam is the capital of Tanganyika, formerly known as German East Africa, now a mandated territory of Great Britain. At Zanzibar the visitors were by previous arrangements assigned to hosts. We arrived about 4.00 P. M. and left at midnight. My host took me in his automobile at once into the country where I could collect grasses. He returned about dark to carry me back to the city. Without this fortunate cooperation I should not have obtained any grasses here.

The island of Zanzibar, with the neighboring island Pemba, is a British protectorate. The chief crop is cloves. At Zanzibar the visitors had their first view of Arabic architecture and culture.

Tanga is the northernmost port of Tanganyika. About 40 miles from Tanga lies the Amani Agricultural In-



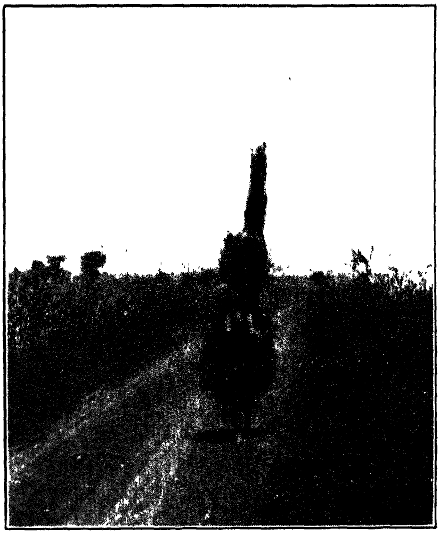
NATIVE HUT NEAR MARANGU

THE VILLAGE FROM WHICH ONE COMMENCES THÊ ASCENT OF MT. KILIMANJARO.

stitute, in the mountains at an elevation of about 3,000 feet. The institution is well equipped for doing scientific work. There are among other facilities a good botanical laboratory and a herbarium. This station was formerly the center of scientific work in German East Africa. After making collections at Amani Mr. Cotton and I went to Moshi by rail on our way to Kilimanjaro. We found that the ascent of the mountain should be made from the village of Marangu about

SENECIO COTTONI

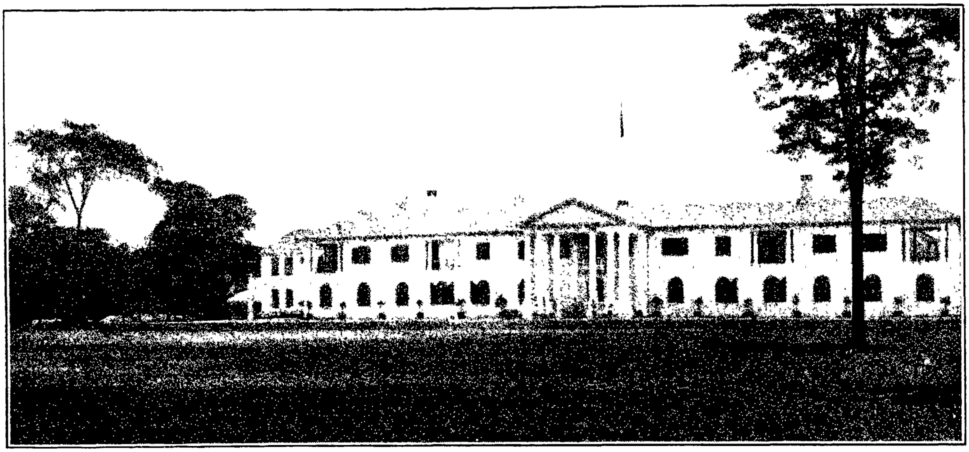
A GIANT SENECIO ABOUT 14 FEET HIGH (THE BASE NOT VISIBLE) AMONG ROCKS ON MT. KILIMANJARO AT ABOUT 13,000 FEET ALTITUDE.



A NATIVE WOMAN

CARRYING A BUNDLE OF GRASS FOR FORAGE. ROAD NEAR MT. KENYA. FIELDS OF MAIZE IN BACKGROUND.

10 miles northeast of Moshi. The ascent of Kilimanjaro is easy up to the limit of vegetation. There is a good trail with a gradual grade. We started from the pleasant little hotel in the morning on mules accompanied by a cook and four porters on foot. The first night was spent at Bismark Hut at about 8,000 feet. The trail led through cultivated land for an hour or so and then through forest. Bismark Hut is a stone rest house with three rooms. The second day we went to Peter's Hut at about 12,000 feet. We soon emerged from the forest after leaving Bismark Hut and passed over grassland with some scrub or bush. Peter's Hut, on an open rocky slope, is a galvanized iron resthouse with one fairly large room. From this point the snow-capped top of Kibo peak is visible over a near-by ridge. The third day was spent in collecting in the vicinity of Peter's Hut, though I went up to about 14,000 feet, which at that point was the limit of vegetation. Here was a beautiful view



GOVERNMENT HOUSE, NAIROBI

THE RESIDENCE OF THE GOVERNOR. A FINE LAWN OF KIKUYU GRASS (*Pennisetum clandestinum*). THE GRASS IN THE FOREGROUND HAS BEEN RECENTLY SET OUT. TO THE LEFT THE GRASS HAS FILLED IN TO A FIRM SOD.

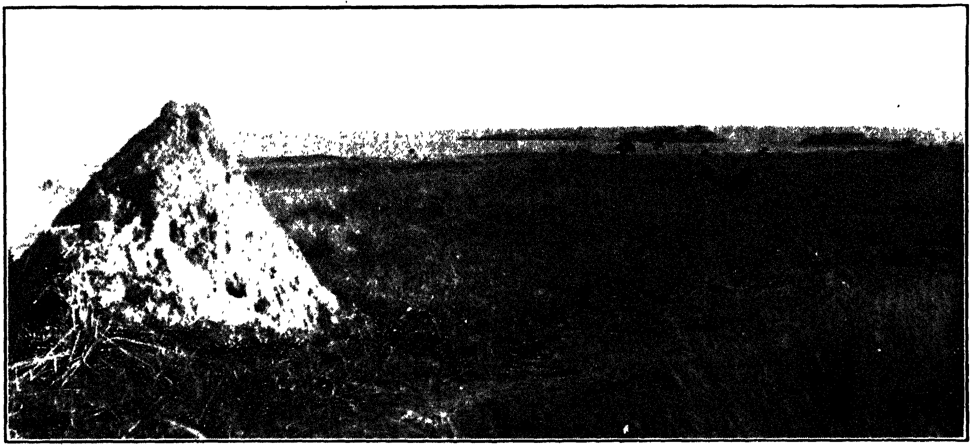
of Kibo, the western peak of Kilimanjaro, with its rounded snow-covered top, bright and distinct in the morning, and said to be the highest peak in Africa (19,710 feet). To the right lay the eastern peak, Mawenzi (about 17,000 feet), the jagged summit without a snow cap. On the fourth day we descended to Marangu.

The grasses of the region above timber line on Kilimanjaro are temperate or alpine species belonging to such familiar genera as *Poa, Festuca, Bromus, Koeleria* and *Agrostis.*

The journey was continued by rail to Nairobi *via* Voi. On the plains approaching Nairobi vast quantities of game were to be seen from the car win-

THE WIVES OF A NATIVE CHIEF NEAR MT. KILIMANJARO

NOTE THE GREAT QUANTITY OF BRASS WIRE AROUND THE ARMS, THE BRASS SPIRALS AROUND THE NECKS AND THE HEAVY ORNAMENTS IN THE DISTENDED EAR LOBES SUPPORTED BY BAND OVER THE TOP OF THE HEAD.



ANTHILLS ALONG THE SHORE OF LAKE VICTORIA AT ENTEBBE. SUCH HILLS ARE COMMON IN TROPICAL AFRICA.

dows, zebras, ostriches, giraffes and various kinds of antelopes and gazelles. Nairobi is a city of about 15,000 on a great grassy plateau at an altitude of about 5,500 feet, distant 330 miles from Mombasa on the coast. It is from this city that most of the hunting trips (safaris) for big game are made.

A two-day automobile trip was made to Nyeri and Nanyuki lying north of Nairobi near Mt. Kenya (17,050 feet, snow-capped).

Through the courtesy of government officials a trip into Uganda was arranged for me. I first went by rail to Kisumu on Lake Victoria. Leaving Kisumu at 10:00 A. M. by a comfortable steamer I arrived at Entebbe the next morning. The altitude of the beautiful Lake Victoria is about 3,700 feet. The following morning I went by automobile to Kampala, the center of agricultural research in Uganda. There is here an agricultural department with a botanical laboratory. Again by automobile I was taken to Jinja, the terminus of the rail-

THE RESIDENCE OF THE AMERICAN CONSUL AT NAIROBI

RIPON FALLS OF THE NILE RIVER

JUST BELOW LAKE VICTORIA. THIS IS CALLED THE SOURCE OF THE NILE.

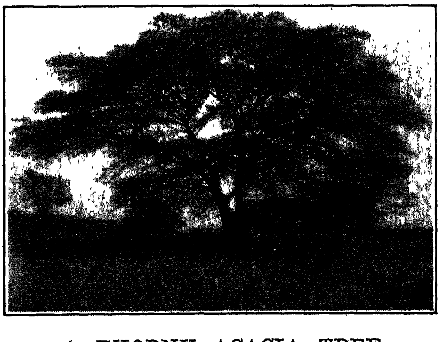
road on Lake Victoria. At this point is the outlet of the lake to the Nile system. This outlet is called the source of the Nile. The return to Nairobi was made by rail, stops of one day each being made at Eldoret, Nakuru and Naivasha. The collecting at Eldoret and Nakuru was unusually good. The grassy plains and rocky hills were ungrazed and the grass flora was very rich. The distribution of the rainfall was such that all grasses appeared to be brought to flowering at just the time of my visit.

In Uganda the most conspicuous grass was elephant grass (*Pennisetum purpureum*), a robust gregarious plant growing to the height of 8 to 10 feet or even as much as 20 feet.

Nakuru and Naivasha lie in the Great Rift Valley, a fault or rift that has been traced more or less distinctly from Lake Nyasa to Abyssinia and even further, according to some. The valley is distinct in Kenya, 40 to 60 miles wide, with a flat floor and escarpments on each side of about 1,500 feet.

Kenya has been known as a great game country. The amazing numbers of herbivorous animals mean on the one hand a large number of predatory carnivores and on the other hand a region rich in grasses to furnish the necessary grazing. Thus the great grassy plateau is a paradise for an agrostologist.

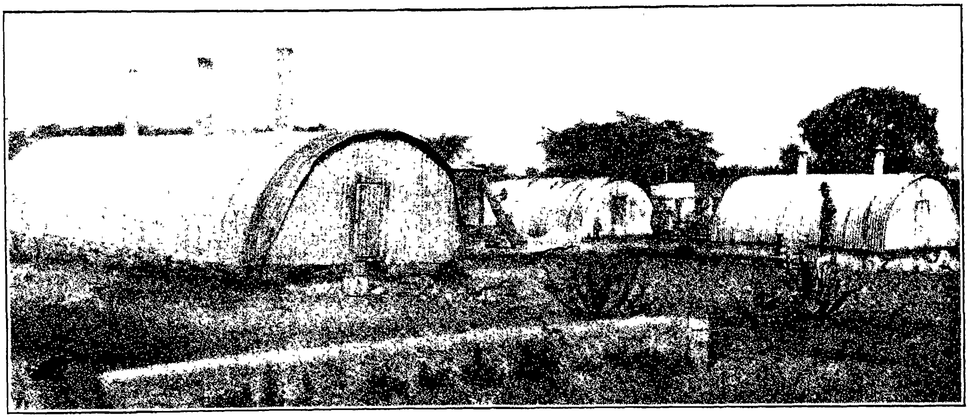
ELEPHANT GRASS
(*PENNISETUM PURPUREUM*)
IN UGANDA ON THE ROAD BETWEEN KAMPALA AND JINJA. THE GRASS IS ABOUT 12 FEET HIGH. ELEPHANT GRASS IS A COMMON AND CONSPICUOUS GRASS IN TROPICAL AFRICA. IT IS USED FOR FORAGE AND HAS BEEN INTRODUCED INTO TROPICAL AMERICA WHERE IT GIVES PROMISE OF SUCCESS.



A THORNY ACACIA TREE
COMMON ON THE PLAINS OF KENYA. THE PICTURE WAS TAKEN NEAR NAIVASHA IN THE RIFT VALLEY.

The taller grasses of the dry plains belong mostly to the tribe Andropogoneae and especially to the genera *Hyparrhenia* and *Cymbopogon*. The genus *Eragrostis* belonging to another tribe (Festuceae) is the richest in species of any of the genera observed.

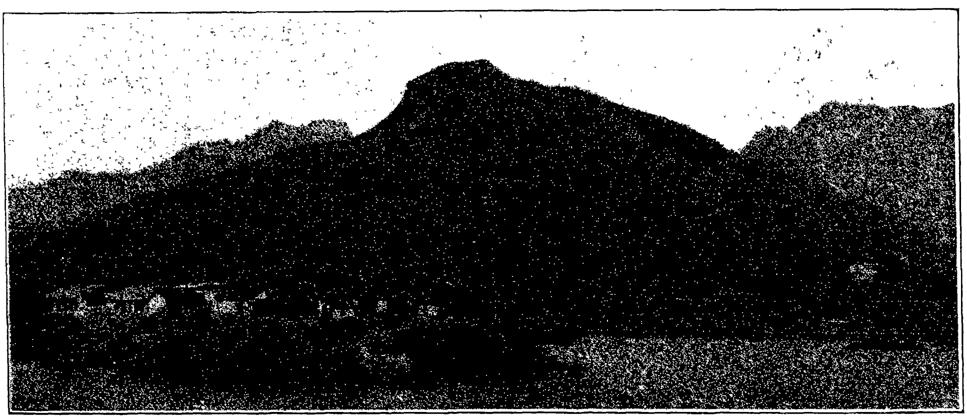
In East Africa one of the native species has been utilized as a lawn grass. This is commonly known as Kikuyu grass (*Pennisetum clandestinum*). It produces vigorous stolons and spreads



GALVANIZED HUTS OF WORKMEN NEAR NAIVASHA

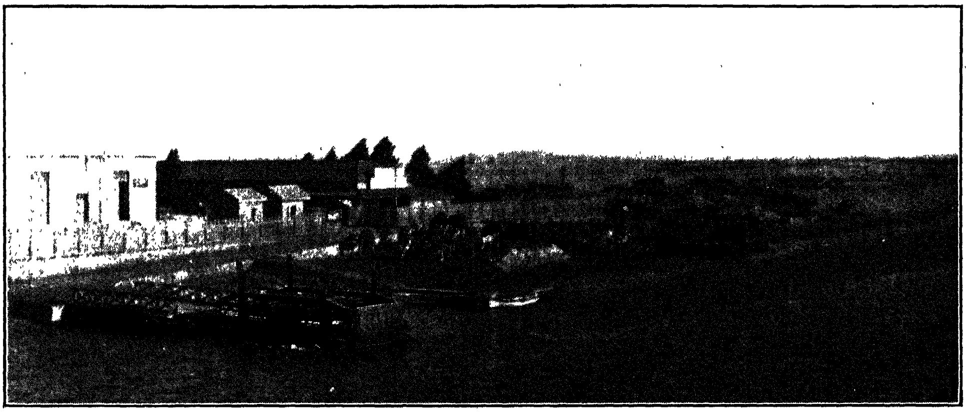
THE RIFT VALLEY NEAR NAIVASHA

THE VALLEY IS FLAT, 40 TO 60 MILES WIDE, WITH A DISTINCT ESCARPMENT ON EACH SIDE.



ADEN, SOUTHWEST ARABIA

IN A VERY ARID REGION. THE PICTURE WAS TAKEN A SHORT TIME BEFORE SUNRISE.



SUEZ CANAL

A STATION ON THE EAST BANK. A LARGE HERD OF CAMELS MAY BE SEEN.

readily when pieces of these stolons are set out. The lawns of this grass are beautiful in color, evenness and density. The texture is somewhat coarser than Bermuda grass (*Cynodon Dactylon*) but otherwise the Kikuyu grass is ideal for tropical regions. It appears to withstand a moderate amount of frost. The limits for availability of this grass as to latitude and altitude have not yet been determined.

On September 28 I sailed for London from Mombasa. Having about two hours to wait before the departure of the steamer, I made a good collection of grasses from a hill near the dock. The return journey was through the Red Sea to Marseilles and across France and the channel to London. A quick change to a transatlantic boat brought me to New York about one month from the time I left Mombasa.

AN ENTOMOLOGICAL SHEEP IN WOLF'S CLOTHING

By Professor WILLIAM L. DOLLEY, Jr.,

PROFESSOR OF BIOLOGY, UNIVERSITY OF BUFFALO

and HENRY G. HAINES[1]

ONE of our commonest insects, the drone fly, *Eristalis tenax*, passes its adult existence unrecognized and avoided by most people because of its extraordinary resemblance to the honey bee. There are few insects except the silkworm and the honey bee that have a historical record equal to that of this interesting creature. Its story begins in the dusk of prehistoric times.

Because it is one of the organisms which have acquired the habit of living in man's vicinity and of following him over the face of the earth, and because recent work has shown it to be splendidly adapted for use in certain types of physiological and genetic investigations, it is important that the known facts about the drone fly be summarized. In the following pages is given the historical record of this remarkable insect and what is known about its life history and distribution.

HISTORICAL RECORD

So close is the resemblance between the drone fly and the honey bee that one is not surprised to read the following words of the great French naturalist, Réaumur: "I scarcely ever dare to take in my hand without hesitating one of these two-winged flies (*Eristalis tenax*)." Nor is it surprising to know that Heliogabalus, a Roman emperor of the third century A. D., was accustomed to play practical jokes on his friends by frightening them in sending them vessels filled with living drone flies. One can imagine the consternation and the reflexes produced by the perfectly harmless flies whose resemblance to angry bees is so marked.

This similarity between drone flies and honey bees is in part responsible for a belief, the Bugonia myth, which lasted for thousands of years, namely, that the bodies of dead animals give rise to honey bees. The earliest record we have of this myth is found in the Bible (Judges xiv). Samson on coming upon the carcass of a lion which he had killed previously is said to have found in the carcass a swarm of bees and honey, to have eaten some of the honey and to have later proposed a riddle, "Out of the eater came forth meat, and out of the strong came forth sweetness." The very fact that he proposed this riddle shows that this belief was wide-spread at this time. It prevailed in North Africa and in some parts of Asia, continued through the middle ages and found expression in the sixteenth and seventeenth centuries.

According to Ovid, Aristaeus, who first taught men to plow and to keep bees, was appealed to for help by certain shepherds who had lost all their swarms of bees. He told them that they might regain their riches from a slaughtered bullock, if they raised suitable altars to the gods, observed certain ceremonies and treated the carcass in a particularly described manner, when swarms of oxenborn bees would enable them to replenish their stores.

[1] The junior author collaborated in this work while an honors student in the University of Buffalo.

Many recipes for making bees are found in the works of ancient authors. Perhaps the most explicit is that given by Florentinus in describing the process used by Juba, King of Northwestern Africa, who died in A. D. 23:

> Build a house, ten cubits high, with all the sides of equal dimensions, with one door and four windows, one on each side: put an ox into it, thirty months old, very fat and fleshy: let a number of young men kill him by beating him violently with clubs, so as to mangle both flesh and bones, but taking care not to shed any blood: let all the orifices, mouth, eyes, nose, etc., be stopped up with clean and fine linen impregnated with pitch: let a quantity of thyme be strewed under the reclining animal, and then let windows and doors be closed and covered with a thick coating of clay, to prevent the access of air or wind. Three weeks later let the house be opened, and let light and fresh air get access to it, except from the side from which the wind blows strongest. After eleven days you will find the house full of bees, hanging together in clusters, and nothing left of the ox but horns, bones, and hair.

Vergil's description of the process is similar. In his "Georgics" he also says:

> De putri viscere passim
> Florilegae nascuntur apes.

One writer specified that the ox should be buried with projecting horns, so that when the horns were cut off the bees could emerge from the cut ends.

Pliny (b. A. D. 23) thought it was only necessary to use the entrails of an ox covered with dung.

Aelian of Praeneste, a Greek writer of about A. D. 200, claims as one of the useful qualities of oxen "that their remains are capable of originating bees."

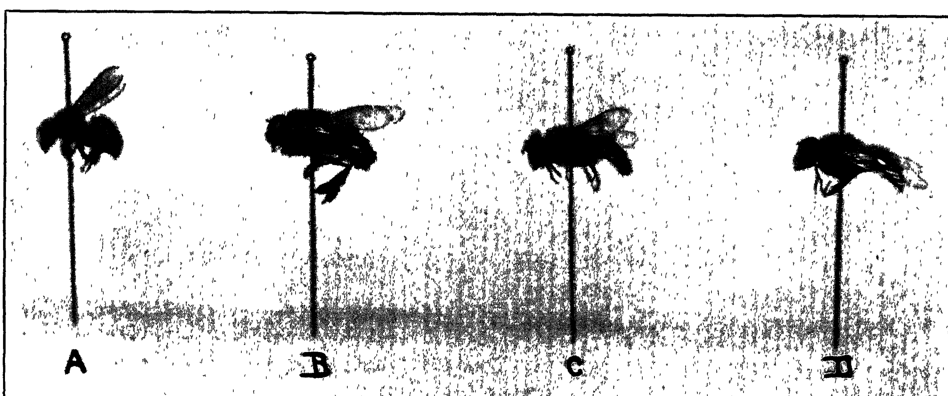
Melanchthon (1497–1560), friend of Luther, considered it a divine provision of nature that bees could be bred from carcasses, and the Italian, Giovanni Rucellai (1475–1525), wrote a poem, "Le Api," containing an account of the Bugonia myth.

Shakespeare in King Henry IV, pt. 2, probably refers to this myth in the following words:

> 'Tis seldom when the bee doth leave her combs
> In the dead carrion.

Moreover, the generation of bees in carcasses was accepted without question by the following seventeenth century naturalists: Aldrovandi, Moufet and Samuel Bochart. Indeed, Moufet believed there were two kinds of animal-bred bees—some bred from lions and others from oxen.

Réaumur was the first to point out that the "bees" which bred in carcasses were flies which closely resembled bees, and Osten-Sacken first identified these bee-like flies as the drone fly, *Eristalis tenax*.



A, WORKER HONEY BEE; *B*, DRONE HONEY BEE; *C*, MALE DRONE FLY; *D*, FEMALE DRONE FLY.
NOTE THE RESEMBLANCE OF THE DRONE FLIES TO THE DRONE HONEY BEE.

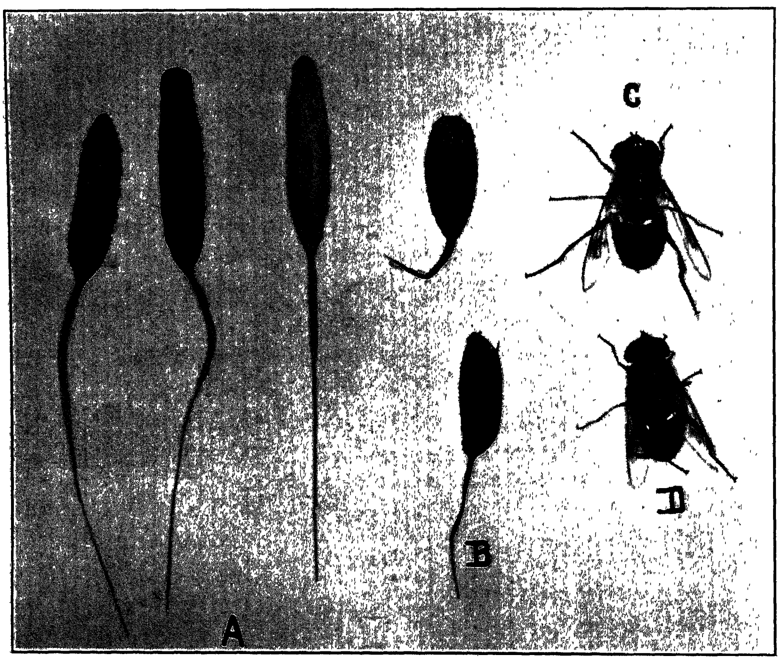
This organism has been well known to naturalists since the sixteenth century. Goedart (1662), Blankaart (1688), Swammerdam (1680), Réaumur (1758) and others described and figured the larva, pupa and imago. Clutius, an apothecary and botanist in Leyden at the end of the sixteenth century, in his book on bees denounced the common error in mistaking bees for *Eristalis tenax*. Vallisnieri (1661–1730), a professor at Padua, and Geoffroy (1762) refer to the fly and its larva. Linnaeus (1766) named the insect and gave the habitat of the larva. Buckton (1895) in his book containing many errors, "The Natural History of *Eristalis tenax*," attempted to present the then known facts about Eristalis. Among others Batelli (1879), Wahl (1899) and Dolley and Farris (1929) have studied the anatomy of the larva. The imago has been used extensively in recent physiological experiments by Professor S. O. Mast, J. L. Wierda and the senior author.

LIFE HISTORY

An outline of the life history of this historic creature is as follows: The imago, or adult fly, deposits its eggs on human feces and in other moist places. The eggs hatch into tiny larvae which grow rapidly into mature larvae. These pupate and remain quiescent for a time and then from the pupae there emerge the active flies.

THE EGGS

A single ovum is approximately 0.04 inch in length and floats when placed on the surface of water. We have several times observed oviposition in Eristalis in captivity. Under these conditions the female fly attempts to find a quiet,



—*Photograph by A. R. Apgar*

A, LARVAE OF *Eristalis tenax*; *B*, PUPAE OF *Eristalis tenax*; *C*, FEMALE DRONE FLY; *D*, MALE DRONE FLY. NOTE THE LONG EXTENDED "TAILS" OF THE LARVAE, THE RESPIRATORY HORNS AT THE ANTERIOR END OF THE PUPAE AND THE DIFFERENCE BETWEEN THE HEADS OF THE MALE AND FEMALE FLIES.

damp, dark corner of the cage in which to lay her eggs. Once oviposition has begun it continues usually until hundreds of eggs are laid. It is a remarkable sight to see the female protruding behind her the long writhing ovipositor which deposits an egg, and then after an interval of a few seconds attaches a second egg to the first, and then after another interval attaches a third egg to the others. This process continues for minutes, the female facing away from the growing mass of eggs. She seems oblivious to her surroundings, yet the mass of eggs is neatly arranged, all parallel and attached to one another. About 300 eggs are laid in one mass. Réaumur states, however, that he saw a female ranging her eggs, 20 or more, close to the water on the sides of tanks and the interstices of tubs; he thought the eggs were not dropped into the water. If a number of flies are kept in captivity in a small cage and they are crawling over one another frequently the eggs are strewn about over the bottom of the cage owing to the females being disturbed.

In July and August females frequently enter the laboratory in Woods Hole, Massachusetts, apparently in search of a place in which to lay their eggs, and during these months a large percentage of the females caught in the open will lay eggs in a few hours if they are placed in a cage and supplied with water and cane sugar. On three occasions flies caught in August and September and placed in a small glass vial laid a number of eggs in the vial within a couple of hours before they could be brought to the laboratory.

Buckton maintains probably incorrectly that there are two varieties of eggs: fusiform, which he says he found in females in early spring, and oval or almost globular fertilized ova, which were secured in the late autumn. He believes that the fusiform ova develop into flies which have incomplete reproductive organs and do not oviposit. According to the same author, the eggs are laid twice during the year, in the early spring and in the autumn.

The Larvae

The larvae are remarkable looking creatures with long "tails" through the end of which they breathe. They have received various names: rat-tail maggots (Réaumur), pig worms (Goedart and Blankaart), aquatic intestines (Vallisnieri) and bog house worms (Swammerdam).

The minute larvae, about 0.12 inch in length, emerge from the eggs in from 24 to 48 hours after they are laid, and grow rapidly until they are about an inch in length. For the first few hours after hatching the tiny larvae are highly positive to light, moving toward sources of illumination. They then become highly negative to light, and remain so until they pupate. If the young larvae upon hatching are kept in water they rapidly drown. We have frequently placed eggs upon the surface of water but found it necessary to remove the larvae soon after hatching to more solid material to prevent their drowning.

—*Photograph by A. R. Apgar*

LARVAE OF *ERISTALIS* FLOATING

NOTE THAT ALL BUT ONE OF THE LARVAE HAVE THE TIPS OF THEIR "TAILS" ABOVE THE SURFACE FILM. THE TWO WITH THEIR BODIES FAR BELOW THE SURFACE AND WITH EXTENDED "TAILS" ARE IN THE NORMAL POSITION OF A FEEDING LARVA. THE ONE IN THE LOWER RIGHT HAND CORNER SHOWS THE APPEARANCE OF THE "TAIL" WHEN IT IS RETRACTED.

The food of the larvae is not known, but they are present in large numbers in human excrement in outdoor privies in Woods Hole, Massachusetts. According to Riley, the adult flies were common in 1870 about outhouses in St. Louis. W. W. Smith in 1890 found the larvae in hundreds in "the atrocious stuff" standing in the barrels of a wool-scouring works and in the stagnant waters and drains near Ashburton, New Zealand. Other investigators have recorded the presence of the larvae in the following places: sewers in Vienna and small stagnant pools frequented by cattle (Buckton); dung heaps, cesspools and putrescent waters (Linnaeus); muddy pools (Kirby and Spence); privies, meadows, brooks, moist cow dung (Swammerdam); pulp of rags used in the manufacture of paper (Geoffroy), and "in corrupted waters, depositories of fecal matter and sewage; sometimes also in waters which are limpid and crystalline" (Batelli). Undoubtedly the larvae in the past were found in the putrescent liquid which surrounds the carcasses of dead animals in the last stages of decomposition, but, as Osten-Sacken says, "It is very rare now to come across a carcass and to see *Eristalis tenax* hovering about it."

Réaumur maintains that he has reared the larvae up to the time of pupation on bread crumbs in water. After many unsuccessful attempts to cultivate the larvae we finally devised a perfectly successful and satisfactory method. Some ground "Ralston's whole wheat cereal" thoroughly mixed with water so that it formed a stiff paste was placed in a depression made in moist soil kept in a glass vessel. Eggs placed on the moist cereal hatch into larvae which live in the cereal and mud in perfect condition up to the time of pupation. Under these conditions the following details of their anatomy and behavior can be seen.

Their color is whitish although it has been described as sky gray approaching a little to brown (Swammerdam), dirty yellow (Batelli), bluish white suffused with pink and showing a certain play of iridescent colors compounded of pale bluish and rosy tints (Buckton). Pliny speaks of a "white gem, Eristalis, which appears to blush at inclinations of the light."

Their most striking anatomical feature is the long "tail," which can be very much shortened by one portion being telescoped within the other or can be enormously lengthened. Réaumur says that he forced some larvae to elongate their "tails" to a length of about five inches. As stated above, these "tails" are respiratory in function. The tip of the "tail" is provided with a tuft of hair-like processes which are covered by an oily secretion, according to Dolley and Farris. Keeping this tip above the surface film the larva burrows deeply into the material upon which it is feeding and breathes uninterruptedly through the "tail."

Two large tracheal tubes easily seen through the transparent integument extend from the tip of the "tail" through the body to two spiracles at the anterior end of older larvae. The anterior spiracles are not present in very young larvae.

The integument is very transparent in very young larvae but becomes much more opaque as they grow older. It is very tough and is further strengthened by being studded all over the animal with almost countless tiny spines.

Through the integument, particularly of those individuals which have just emerged from the egg, can be seen plainly at the anterior end of the animal black chitinous bars which are a part of a complex pharyngeal mechanism described well by Miall and others.

According to Batelli, the body of a larva is divided into nine segments

distinguished by furrows with raised edges. On the anterior segment there are present two antennae or sensory papillae. We have been unable to confirm Batelli's statement, "Beneath the antennae are two pigment spots which function as eyes."

The larvae are provided with seven pairs of very short "feet" or prolegs. They have been described by Swammerdam in these words:

> The extremity of each foot is circular and armed like the prolegs of a caterpillar with a large number of fine hooks; the feet can be retracted at pleasure. The hooks are set in a double circle, the circle next to the tip being made up of larger and less numerous hooks than the other.

Another striking anatomical feature is the anal glands—several little pouches which are protruded from the anus at the base of the tail when the animal is quietly feeding. These when extended are wafted to and fro rhythmically but are immediately withdrawn into the larva when it is disturbed. The function of these glands, which are present in larvae of all ages, is not known, but is probably either excretory or respiratory, for they are richly supplied with tracheae.

When a number of larvae are together feeding in a liquid medium and floating at the surface they are frequently gathered in groups with their "tails" much intertwined, "tied into regular knots," according to Buckton. In among these groups are the cast-off skins of the larval stages.

The method of feeding, according to Réaumur, is as follows:

> The larva, living in the midst of abundant food, works over its food much as a pig investigates a pile of refuse with its snout. When enough particles have been scraped loose by the roughened surface of the tuberculatory swellings, they are sucked into the muscular pharynx, where they are removed from the water by a straining apparatus.

Their locomotion has been described by Buckton in these words:

> Though never active in their movements, the larvae, while floating, show a continual constrictive and undulatory motion, which proceeds from the tail to the head, and gives the appearance of creeping like a caterpillar. During this action the front tubercles are alternately protruded and retracted, the water being taken in by gulps and forced backward to the pharynx.

Although they are remarkably tough and resistant to certain unfavorable conditions it is difficult to believe Linnaeus' statement that some larvae which were accidentally introduced through the water into pulp employed in a paper mill survived the pressure of the rollers used in the manufacture of paper. According to Buckton, they will live "many days in clear water free from vegetable or animal matter," in brackish water and in the briny spent-liquors remaining after the curing of bacon. We have repeatedly observed their remarkable resistance to many killing fluids. They will live for several minutes in "Flemming's" containing osmic acid and in other strong fixatives.

The duration of the larval period is in the summer months about two weeks. This period may be lengthened or shortened, however. If the larvae are kept under unfavorable conditions, as in human feces for some reason unsuitable to them, they will leave the material before they are full grown, pupate and hatch into flies much smaller than the normal ones. E. J. Farris in some unpublished experiments kept some larvae living as larvae for over 70 days by placing them in human feces in temperatures a few degrees above freezing. According to Krüger, *Eristalis tenax* spends the winter months in the larval state.

Osten-Sacken maintains that there are a dozen well-authenticated cases where Eristalis larvae have been voided in human excrement. These were no doubt due to the consumption of contaminated water.

The Pupae

When the time for pupation comes the larva leaves the liquid in which it

is living. "Its body becomes encrusted with earthy particles which adhere in consequence of the sticky exudation from the skin," according to Miall. The body and tail become much shortened. The tail and the integument of the body become dark brown and hard.

> After twenty-four or thirty-six hours from the time of pupation two pairs of horns appear at the head end. The fore pair is about half the length of the other, and the two pairs often curve towards one another. The fore pair, when diligently observed, are found to be present in the larvae, but they become much more conspicuous at the time of pupation by the smoothing out of the adjacent parts. The large posterior pair appear for the first time shortly after pupation. The horns are really the respiratory organs of the pupa, as is clearly shown by the large tracheal trunks which enter them (Miall).

According to Buckton, the pupae are buried but not deeply in mud. Swammerdam observed the larvae "fixed to the walls of country cottages where they had climbed up to twice a man's height" in order to pupate. Réaumur allowed some larvae to pupate in empty boxes where "they glued themselves to the wood, and if only slightly attached by the hinder part of the body, the transformation was successfully effected: but when the whole of the under side stuck to the wood, the larva perished." We have many times repeated Réaumur's experiment but have never seen larvae destroyed by having the "whole under side stuck to the wood." Pupation is accomplished even though no attachment is made.

The duration of the pupal phase is correctly stated by Miall to be from eight to ten days "in a favorable season." Swammerdam, however, maintains that it lasts about eighteen days. Buckton is probably correct in saying that this period varies with the temperature, but offers no evidence for his statement that it ranges from twelve days to several months. He also states that pupation occurs from the end of June to late October.

Réaumur is probably incorrect, as Miall intimates, in maintaining that before the fly emerges from the puparium it must turn itself completely around in its cocoon.

The Imagoes

The young flies have been repeatedly observed emerging from the puparia. At first they are much lighter in color than the older insects and their wings are much crumpled. Within a few hours, however, the wings have expanded, the normal color has been assumed and the flies are able to fly vigorously.

The resemblance of these perfectly harmless flies to drone honey bees is shown strikingly in the photographs. One does not wonder that they are so frequently confused.

Eristalis tenax also resembles bees in showing somewhat similar color varieties. The males usually have abdomens which are yellower than those of the females, but both sexes vary in the relative proportions of the distribution of the black and yellow pigment on the abdomen.

Moreover, the flies are found feeding with bees upon the nectar and pollen of various flowers, changing readily from one to the other as the season progresses. We have seen them feeding in large numbers upon the blossoms of the common privet, wild mustard, buckwheat, various asters, golden rod, dandelion and occasionally on wild carrot. Near Buffalo, New York, when all other flowers have been killed by frost Eristalis may still be found feeding on dandelion blossoms.

The feces of flies feeding in the open are colored yellow by the numerous pollen grains which have passed through the intestinal tract. The feces have the peculiar odor characteristic of a beehive.

The flies are very common in Woods Hole, Massachusetts, in July, August and September; in Buffalo, New York,

in September, October and the early part of November, and in Baltimore, Maryland, and Ashland, Virginia, in October, when many individuals come into dwellings and laboratories, probably attracted by the higher temperatures within the buildings. According to Banks, Eristalis is common in April, July, September and October near Sea Cliff, Long Island, New York. Buckton states that he has found one female near Haslemere, England, in December and several females as early as March 15.

The time at which the flies become sexually mature is not known. A large percentage of the flies captured in the open in Woods Hole, Massachusetts, in July and August are sexually mature and will deposit their eggs on being taken to the laboratory, as stated above. However, practically none of the flies caught near Buffalo, New York, in late September, October and November will oviposit when brought into the laboratory. Out of hundreds of flies caught at this time only about three oviposited. According to Buckton, the fly he found in December was "an impregnated female, with numerous ova." He also records having found immature females on "May 18, June, August, to October 8," and "impregnated" females from September 12 to late October. He says that sometimes immature forms comprise the larger number of the flies on the wing.

The same author maintains that the female flies hibernate during the winter, crawl out of their hiding places in the spring and soon become actively engaged in oviposition. However, that the adult flies do not hibernate in New York is suggested by the facts that at room temperatures they demand constant access to water in order to live, and that the flies die rapidly when placed in temperatures several degrees above freezing, as found by E. J. Farris in some unpublished work. Opposed to this view is the statement of Buckton that the single female he found in December had been subjected to a temperature of 13 degrees Fahrenheit.

We have made numerous attempts to keep the adult flies living in the laboratory under artificial conditions. In the most successful of these several female flies were kept in splendid condition for four and one half months at ordinary room temperature. They were in a small wire cage. Water was always accessible. Their food consisted of "Ralston's whole wheat cereal" ground fine. This was mixed with fine cane sugar and kept moist. When placed under these conditions the flies of both sexes live well for about two weeks. Then they begin to die and a small percentage of the females only survive for long periods.

Our knowledge of the parasites of Eristalis is slight, as may be expected. According to Buckton, Eristalis is accompanied by its natural parasite, *Tropidopropria conica*, Tab. We have several times observed the ordinary bald-faced hornet, *Vespa maculata*, feeding on the drone flies, and on a few occasions have caught flies bearing one or two mites of an undetermined species. W. H. Bernhoft has discovered that they also harbor a minute intestinal parasite probably closely related to if not identical with the flagellate, *Herpetomonas muscae-domesticae*, found in the intestine of the house fly, *Musca domestica*.

Distribution

The distribution of the drone fly is practically universal. Frauenfeld says: "*Eristalis tenax* is in its ways a remarkable phenomenon, for which there does not seem to exist any other boundaries in time or space (vertically or horizontally) than those which put an end to insect life in general." It occurs

throughout the United States, is abundant in Mexico and Canada and has been reported throughout Europe, in Lapland, China, Japan, southern Italy, Corsica, Malta, Algiers, Gibraltar, Madeira, near Mount Sinai, Canary Islands, Madagascar, New Zealand, Bourbon, Siberia, Northern Persia and in Syria.

The history of Eristalis in the United States is interesting. Its first recorded appearance in this country was in St. Louis in 1870, but it probably did not exist in this locality very long previously. The first specimen seen on the Atlantic coast was found by Osten-Sacken in Cambridge, Massachusetts, on November 5, 1875. The next year several were seen in Newport, Rhode Island, in October and November. In 1877 hundreds were caught in this vicinity. A few years later it was reported from nearly all the states, including California and Washington. Osten-Sacken very properly remarks: "This sudden appearance of *Eristalis tenax* in all parts of the United States, in localities thousands of miles apart, and within a short period of three or four years is a very extraordinary phenomenon and requires an explanation." According to the same author, Eristalis migrated from Japan or eastern Siberia to the North American Pacific coast perhaps long ago, but did not spread across the continent because the necessary conditions for its existence were absent. When, however, man moved from the Pacific to the Atlantic in sufficient numbers Eristalis followed him, breeding in his excrement, and when once the Eastern seaboard was reached it very quickly became abundant and wide-spread.

A somewhat similar thing happened in New Zealand where, according to Osten-Sacken, Eristalis was first noticed in October and November, 1888, but two years later was found to be widely dispersed in large numbers.

THE PHYSICAL BASIS OF INTELLIGENCE

By Dr. CLEVELAND S. SIMKINS
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ONE could say at the very outset that the brain is the physical basis of intelligence and let it go at that, but the inquisitive investigator would yet wonder why some individuals are smart and others dull. Doubtless all the different types of mankind now classed under the name *Homo sapiens* belong there biologically, but are downright mental disgraces to the title. Many outstanding individuals would offer no objections to the compliment, sapient, and yet it does seem a far-fetched use of the term to apply it to a Tasmanian or a microcephalic idiot. What are fools, morons, seers and sages? The every-day speech of man has recognized the differences in mental ability, and a crude but working classification has sprung into common use which in a vague sort of way takes cognizance of brains in the proper cataloguing of the mentality of its individuals.

What differentiates the fool from the sage? Both have brains. One has more than the other, one has a greater mass, a greater weight and is therefore more intelligent. We shall not stop here to define intelligence, but hurry on as if we knew and in the determination of its physical basis offer a definition. The brains of normal individuals do vary in size and weight, from small brains to very large ones. There are limits below or above which the variation can not go without encroaching upon the abnormal. Abnormal mental types have brains of abnormal size which range from the microcephalic idiots at the bottom to abnormally enlarged brains at the top, but even between these two extremes, where mental ability must be classed as normal or borderline, there is wide variation.

It has been generally believed that large brains reside in large heads, and some years ago a series of scientific investigations was undertaken to determine the correlation between head size, brain size and intelligence. No physiological correlation was found, and the association between head size and intelligence was relegated to the discard, perhaps too hastily. Even if there is no recognized correlation between head size and intelligence in the normal in a physiological sense there is some definite association in the pathological sense, for it is now well established that heads abnormally large or small have something wrong with the brain. Abnormal mentalities reside in abnormal heads, which expresses itself in size or shape of the cranium, but no particular size or shape can be said to be characteristic of any given condition. The size and shape of the head have little significance in determining the intelligence, but the modern neurologist makes use of it in establishing the departure from the normal, in which case it is a clue of valuable neurological significance.

The size of the head, and that usually is an index to the size of the brain, can not be relied upon as a measure of intelligence; its use in the abnormal is mainly for diagnostic purposes. However true the above may be, there are many investigators who are strongly convinced that the size of the brain is a general index to the intelligence of the individual and in support of that contention have cited the fact that the brains of our intellectual leaders have been and are above the average. The fact that some great men have small brains lessens the validity of this contention.

The absolute size of the brain and the

methods of its calculation from measurements of the head is a very important adjunct to the equipage of neurologists engaged in determining the degree of mental defectiveness and the limits of departure which can be classed as normal, but measurements in themselves are only an indication that something might be wrong, so it became necessary to seek elsewhere for a reliable physical basis of intelligence. The deeper search revealed the convolutions of the cortex, and at once the relation of the fissured and convoluted cerebrum to intelligence in general was attacked. The number, depth and length of the convolutions were investigated with the hope of discovering some correlation between the mental ability of the individual and cortical configuration. There can be no doubt that convoluted brains do not arise in mammals of low order, but gradually increase in complexity until the genus homo is reached. It is also quite true that the convolutions greatly increase the surface area of the neopallium. Inasmuch as the gray matter is continuous over the whole surface area, into the depths of the gullies and on the tops of the ridges too, it follows that the more numerous the fissures and the deeper the gullies the more extensive the area of the gray substance upon which it has been thought intelligence depends.

The convolutions, their extent, their configuration and depth have been carefully studied and compared, with little success, so far as correlating the mental ability of the individual with the surface area is concerned. There was found to be a broad correlation physiologically, but so broad and so general that it was inaccurate for scientific measurements or determinations. The weakness was most pronounced in some cases of mental defectives. As a general thing the surface area of the normal individual is greater than that in low mental types, but in some cases the surface area of the dement is even higher than the normal.

It does appear, then, that neither the size nor the surface area of brain can be used as an accurate and infallible guide to the determination of the mentality of the individual, and brains so classified can not be indisputably placed in categories of high or low intelligence. It then becomes necessary to seek elsewhere for the physical basis, remembering, however, that size, weight and surface area constitute important aids that can not be ignored, for it is well established that leaders in all lines of intellectual endeavor have brains and bodies that stand out as heavier, larger and with a greater surface area than mediocre or inferior individuals. After all, the contention that great men have greater and heavier brains is true to a limited degree. A much more reliable basis than either mass or surface area is the thickness of certain layers of the cortex, which must be explained to be understood.

If a section through any part of the cerebral hemisphere is examined carefully with the unaided eye it will be seen to be composed of an outer layer of gray and an inner layer of white substance. The outer layer is the cortex and the inner is the medulla. The outer layer is made of cell bodies mostly, while the medulla or white substance is composed almost exclusively of fibers. The cortex is much thinner and is made up of alternating strata of lighter and darker materials which can be recognized upon close inspection with a hand lens. From without inwards these layers of the cortex are: (1) superficial band; (2) a superradiary band; (3) an outer band of Baillarger; (4) an inner band of Baillarger. These bands can be recognized in the fresh brain and are not to be confused with the layers that can be recognized when the brain is fixed and stained and examined under the microscope. The histological examination shows that there are five layers, the first one being a superficial fiber lamina, which is made up of nerve fibrils, neuroglia (support-

ing) cells and tangential fibers that interlace in a varicose network and yet maintain a general parallel course with the surface. The second layer is composed of pyramidal cells of large, medium and small size, whose axones run inward, that is, out-bound impulses course over them. The third layer is a granular cell layer formed of closely packed Golgi Type II cells. The fourth is an inner fiber lamina and is made up of medullated axones and an occasional large pyramidal cell. The fifth is a polymorphic cell layer and consists largely of polymorphic neurons. The only correspondence between these histological layers and those of the fresh brain is this: the outer line of Baillarger agrees closely with the middle or granular layer, while the inner band of Baillarger lies at the same level as the inner fiber lamina.

Watson proposes a simplified terminology for the layers of the cortex and reduces the number from five to three. He includes the two outer layers, outer fiber lamina and pyramidal cell layer, in his supragranular cortex. The middle layer he would call the granular cortex, and the two inner layers, inner fiber lamina (layer of axones) and the polymorphic cell lamina, he would include in the infragranular cortex. From the developmental and functional points of view this simplification is an excellent one and takes in all that is essential in the determination of mental reactions. From without inwards they are, supragranular, granular and infragranular cortex.

There is some very interesting information in the order in which these layers arise. During the first three months of gestation there takes place in the developing brain a proliferation of undifferentiated neuroblasts, that is, the cells of the brain multiply only. But during the fourth month, usually along toward its close, a change takes place in this unilayered condition. On the external surface there differentiates a fibrous lamina so that there are now two layers, the fiber lamina and the neuroblastic layer. The fiber layer undergoes no significant change from the fourth month on to maturity; it merely thickens to about double its depth. The neuroblastic layer gives rise to the polymorphic cells in the fifth month, by the differentiation of cells from the internal surface. There are now three layers, the outer fiber lamina and the internal polymorphic cells while the undifferentiated neuroblasts lie between the two. During the sixth fetal month this layer of neuroblasts produces the granular layer and the pyramidal cell layer, the chief part of the supragranular cortex. All five histological layers are formed by the end of the sixth month but none of them are as thick as they will be at birth. It is very significant too that all five layers do not thicken at the same rate.

The infragranular cortex arises first, fourth month, and by the end of the sixth month has attained 75 per cent. of its total adult thickness; by six weeks after birth it has reached 82 per cent. of its total adult thickness, and shortly after the onset of the prepubescent period it reaches its total adult thickness. The infragranular cortex is made of axones in the inner fiber lamina and the polymorphic cells, so that it has a neuronic part and a fibrous part. The incoming impulses from the vegetative organs come to this infragranular cortex over the axones of the inner fiber lamina to the granular cortex and out to the vegetative organs by way of the polymorphic cells. Inasmuch as these outgoing impulses operate the sexual and vegetative functions it is only natural that they should be formed early and be in working order at birth. The polymorphic layer can not function without the inner fiber lamina, so it is formed at the same time, while the very important granular cortex arises next to the polymorphic layer.

The granular cortex receives and stores the incoming impulses destined for the superimposed layer, hence it does not reach its total thickness as soon as the infragranular cortex. At birth the granular cortex is 75 per cent. of its total adult thickness; at the sixth fetal month it was 50 per cent. The mechanism for operating the lower animal functions is this: inbound impulses traverse the afferent axones to the inner fiber lamina to the granular cortex, where they are received, stored and discharged over the cells of the polymorphic layer to the viscera. The three layers, inner fiber lamina, polymorphic cell lamina and granular cortex, are parts of the primitive pallium and in some mammals constitute the entire layers of the cortex.

The pyramidal cell layer, the most important component of the supragranular cortex, is merely recognized at the sixth month. At birth it has increased to 25 per cent. of its total adult thickness and at six weeks after birth has increased to 50 per cent. During the next six weeks it increases about 10 per cent., so that it attains 60 per cent. of its total adult depth by the middle of the first year. This layer is concerned with those types of reactions which are commonly referred to as intelligent, and though 60 per cent. of the total number of cells are present six months after birth they are not all working because the process of myelinization has not been completed on all of them and no axone is in perfect working order until it is medullated. In the supragranular cortex reside the highest cortical functions such as control, inhibition, reason and educability. The layer being thin and imperfectly working at birth has very little influence on the infragranular cortex, and the baby shows no control over or inhibition of the vegetative apparatus. The supragranular cortex does not increase at the same rate in all individuals nor does it grow at the same rate in both sexes.

Prior to 1920 there were no studies available on the growth of the brain after birth. In that year Berry and Porteus reported after a study of ten thousand brains that there were definite periods of growth in the human brain from birth to maturity. The first period, the prepubescent, comprises the first eleven years of the child's life. During those years the brain of girls reaches 91.3 per cent. of its total expected volume, while the brain of boys reaches 88.8 per cent. of its adult size.

During the twelfth year there is a decided and definite slowing up in the rate of growth, and in this resting period the brain increases only .6 per cent. in both sexes. This resting phase occurs just before the onset of puberty, and it is quite significant that high-grade aments show abnormal mental traits at this period.

The third period includes the thirteenth and fourteenth years, the period of puberty, during which the brain of girls increases 3.4 per cent. and that of boys 2.2 per cent.

The fourth is the postpubescent period, during which the brain of the female increases 4.7 per cent. and that of the male 8.4 per cent. It would appear that the brain of females reaches maturity slightly in advance of the males. It has been shown by Bolton that the postpubescent increment to the cortex is the one that most often fails to be added, which shows up more or less decidedly in the mental reaction of the individual just as the sexual mechanism matures. In some cases even the second and third increments are not added, and a mental defective of the ament grade results. When the postpubescent addition is not made the controlling and inhibiting impulses are either absent or feebly developed, and the behavior of the individual approaches the animal level. The infragranular cortex is rarely diminished but the superimposed layer is, and that may result in a small head. The

measurement of the head and the calculation of the cubic volume of the brain therefrom is not at all an accurate determination of the mentality, but when the deviation is so far from the normal that it is startling then do we find some type of mental defective.

The high cubic capacity of the brain may be due to two totally different things. The size of the brain depends upon the number of cells composing it, but not all the cells of the brain are neurons; some are supporting cells. Large brains made up mostly of neurons produce seers and sages, but large brains made up of a superabundance of supporting tissue produce the big heads of inferior and mediocre ability. Large brains of inferior type are caused by the conversion of too much potential nerve stuff into supporting stuff during the early differentiation of the layers of the cortex.

One may assume that if the cortex stops its growth or is stopped by some cause known or unknown the normal micrometric depth is not reached and the mental reactions suffer because of it. Some internal secretions may stimulate the cortex to renewed growth as the thyroid does in cretinism, but for other causes of arrested or delayed growth of the supragranular cortex there is yet no stimulating substance known. In the idiot the thickness of the supragranular cortex is but 25 per cent., or less, of the normal value. In the imbecile the thickness is 25 per cent., and in some types of dements the depth may be no more than 60 per cent. of what it should be in the normal. In all forms of mental backwardness and lack of intelligent response and adjustment there occurs a retardation in the growth of the supragranular cortex, or a direct loss of cells from the pyramidal layer. In the imbecile and idiot the infragranular cortex is of normal thickness, as is also the granular cortex, so that the vegetative functions have the same efficient mechanism and the intensity of the impulses arising therefrom is in no way diminished, but the efficient mechanism for the control of these functions is lacking. The ability to reason, make mental adjustments, to be educated, is hampered or absent, because the physical basis for such high mental functions is lacking.

There is a limit to the size of the brain that permits of intelligence. If the brain is smaller than 930 grams there is no possibility of having any human intelligence, but this is a far less important consideration than the relative thickness of the layers of the cortex. Mankind did not acquire the laminated cortex at a single bound, but gradually through the progress of the ages it was added little by little. Probably the ability to become so endowed with a great cortex was bequeathed to man by his protohominid ancestors. In the cortex of mammals the same layers are found as in mankind, but the relative thicknesses are vastly different. The infragranular cortex is of about equal depth or the variation is slight enough to be ignored. The granular cortex is about equal. The supragranular cortex, however, is almost entirely absent, and even in cases where it is present it is about one fiftieth as thick as in man. In this fact lies the utter absence of control and inhibition that the animals manifest in the matters of food and sex.

The explanation of cortical function is to be found in the connection of incoming impulses with the outgoing ones and the passage of the impulses through the several layers of the cortex. The interconnecting neurons are relatively short and are interposed between the termination of the afferent axones and the origins of the efferent fibers, where they occupy the relative position of a rheostat in an electric circuit. In the layers of these internuncial neurons the incoming impulses are arrested, stored up, lost or discharged. It is this function of arresting, sorting, modifying, storing, dissi-

pating or discharging impulses that is responsible for the phenomena collectively called "mind." Impulses that are brought to the cortex by the afferent axones reach the granular layer first; here the manifold duty of sorting and storing takes place, involving a limited number of neurons. Even though the actual number of neurons is large it is limited, and the possible connections that can be made depend upon the actual number of neurons present in the cortical layers. Not all incoming impulses arouse a "set up"; some are lost, others stored; but some induce a complete circuit and are discharged over the appropriate, or inappropriate, pathways. Thus does this function, mind, take no cognizance of intelligence. If something interferes with the development and operation of the internuncial neurons a corresponding impairment of the mind results. The development may go on to normal and some disease or poison destroy many of them so that interconnecting function is hindered, a departure from the normal takes place which may go so far as to constitute insanity. Mind is function, the operation of the machine, the interconnections formed between the internuncial neurons for the transmission of impulses through the cortical layers.

But what of intelligence? At first blush it may appear that intelligence has no place in this scheme. The mechanical operation of the units is enough seemingly to determine the reactions, about which there is nothing mysterious even though the operation is exceedingly complex. Intelligence depends upon factors which are more subtle, and two in number. The first is the number and nature of the neurons and the second is the number and nature of incoming receptor impulses. Mental reactions, which can be measured, should not be confused with intelligence, which can not be measured. They are not distinctly different phases of the same thing. It can very readily be seen that if there are many neurons the incoming impulses will have a greater variety of pathways over which to travel and there will be a greater chance for them to be stored; there will be a greater number of possible selections. Perhaps the storage depends upon the number and quality of the incoming impulses and the number of repetitions, and this in turn depends upon the number of neurons in the supragranular cortex capable of entering into the reaction. Impulses are continuously shot into the cortex where certain combinations of the neuronic arcs are made, and the more neurons there are present the more appropriate will the reaction be; the more appropriate the reaction the more intelligent the response. Mind depends upon the incoming impulses which are always more numerous than the outgoing ones, and the intelligence of the reaction is quite dependent upon the possible "hook ups" that can be made in the circuit. Mind is the operation of the mechanism; intelligence is the use of the number and kind of units involved in this mechanism. The units are the neurons in the supragranular cortex, influenced by the number and kind of impulses that come in over the receptor neurons. It is at once evident that the reaction which any individual makes to incoming impulses will be largely, if not entirely, governed by the arcs that can be established between the incoming and outgoing neurons. The previous experience of the organism, the training and the use to which his neurons are put, have so much to do with his intelligence. It must not be lost sight of, however, that if the number of neurons is small the chances of being able to make an intelligent "hook up" are reduced to a minimum, while if the number is large the chances are greater, and two individuals with the same training can not profit by it to the same extent.

In the evolution of the vertebrate

brain nature has added a series of coordinating brains on top of the old. At the top in the first stage lies the midbrain; in the next stage thalamo-striate brain was added, and on top of that was placed the infragranular cortex. Finally in man the supragranular cortex was added. Nothing has been taken away; each additional part was intimately connected with the old, forever increasing the complexity, ever increasing the number of neurons at the top and the possible number of combinations between them. This soon becomes so complex that the experimenter can not predict beforehand just what pathway the outgoing impulse will take, and is able at best to form only a very general prediction. The destination of the outbound impulse impels his behavior, in the sense of the neurologist, not the psychologist. This can not be foretold definitely because of the complexity of the neuronic arcs and the numerous possible routes over which the outbound impulse may be dispatched.

Psychic reflexes, emotional reflexes, are delayed responses, instead of immediate, to the incoming receptor impulses which reach the supragranular cortex, the most recently added part of the pallium. Here are the most numerous and most complex neuronic arcs, the switching system for the tracks over which the outwardly dispatched impulses are to travel. Psychology has concerned itself with these outbound tracks which are, after all, only part of the entire process and can claim but a small province in the great empire of brain physiology.

Probably the higher reflexes are essentially similar to simple ones but are more involved because of the concatenated series of neurons and neuronic arcs over which the impulses must go before they occasion a display, the collective phenomena of which constitute mind. There can be no mind without neurons, and there can be no intelligence without neurons and incoming impulses. Upon the neurons, not only their nature and number but also their use, does intelligence depend.

The physical basis of intelligence, then, is the neuron, especially those neurons now residing in the supragranular cortex. The number of neurons in that layer determines its thickness. If few are ever developed the individual is an ament; if more are formed the individual may become a high-grade ament or moron. If the postpubescent increment has been partly or completely added and then is destroyed the individual becomes a dement. If the normal thickness is attained without subsequent destruction the individual is normal in his mental reactions. The normal varies in thickness, but within definite limits. If the layer is very thick, which means that many cells are present, the brain will be large and the layers thick, and the individual will be a multineuronic genius. The brain may be just as large in another individual but the cells not neurons but neuroglia, in which case the brain will be that of the big-headed type of inferior or low intelligence. If the thickness is average the intelligence can not rise above that level.

Fools, morons, seers and sages are such by virtue of the neurons in the supragranular cortex and the use to which these neurons are put. The brain must receive before it can put out, and of course the more there is to receive the more there can be accomplished. It is the function of correlation, integration, association and storage of impulses by the internuncial neurons and their use which occasion intelligent responses and the more of all this the individual is called upon to do the more attuned will his life be to the world into which he has been cast.

THE SCOURGE OF YELLOW FEVER: ITS PAST AND PRESENT

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THE present generations dwelling in the Southern states, in Cuba, Panama, Mexico and Central America, living in the midst of excellent health control and thus unafraid of the great plagues that formerly overran certain portions of the earth, give little heed to the possibility of that terrible epidemic disease, yellow fever, which for centuries (1650 to 1900) ravaged the regions above mentioned, attacking all classes of society, causing the death of thousands, paralyzing the activities of man, so long as it remained in a given locality, leaving behind, after its disappearance, a trail of woe and sorrow, of poverty and distress. In some parts of the Gulf Coast (Gulf of Mexico) where the disease appeared periodically, as in Texas, Louisiana, Mississippi, Alabama and Florida, the people were barely recovering from a summer's visitation before a new invasion or a renewal of the infection took place, so that its material progress was in this way seriously curtailed, not to mention the consequent emigration of a fair part of the population into other states, in an effort to escape the threatened calamity during the hot months of the year.

One of the features that stamped yellow fever as a particularly fearful disease was its spectacular appearance, the sudden onset and quick death of those attacked, usually within a week or ten days after their first symptoms. Other diseases, not less dreadful, bubonic plague, typhoid fever, typhus, are more insidious in their presentation, last longer in their course, and the families of those afflicted enjoy a certain period of hope that makes the disillusionment less painful. But at certain times in some of the epidemics of yellow fever the people became panic-stricken, many fled as soon as they could, others even abandoned their dying relatives, and there were many occasions where a great exodus of the population made it impossible to bury all the dead. Many communities of the surrounding country, where yellow fever had made its appearance, established the so-called "detention camps" to prevent free emigration from the stricken towns, and the old shotgun quarantine when deputies carrying firearms readily shot at any one trying to cross sanitary cordons without a previous thorough examination and protracted detention to insure his enjoying absolute freedom from infection. In the "detention camps" of the South, many died from privation and exposure, as they were seldom prepared to care for the improvident emigrants who frequently at the same time congregated there. The period of observation in some of these human (or inhuman) corrals varied according to the opinion of the local authorities or of the people from two weeks to the preordained forty days. And then when a case of yellow fever developed in any of them, as was often the case, it became necessary to move camp, and, as it was then customary, everything not absolutely necessary to life or that had had any contact with the case was set afire for its purification, the only means of disinfection then deemed effective.

It seems to us to-day like the memory of a nightmare in the course of our lives, but I have not exaggerated or overdrawn the picture of those awful days. In fact the tragedy was greater than I have depicted, for along with abandoned homes went robbery and pillage, with the loss

of parents, the hunger of children, the despoiling of young girls, the abuse of brute force, and with the fear of impending death came the relaxation of moral ties and restrictions (though one would think it would be otherwise), this being a human phenomenon that has been witnessed in mostly all great calamities of any duration, crime increasing in all periods of general distress. Along with this, however, as also observed in all great conflagrations, acts of self-denial and heroic altruism were not lacking amongst the inhabitants of the afflicted communities.

We have been taught to think that yellow fever was a disease of the South, of the tropical or subtropical regions of America; but when we come to delve into the musty pages of history, we find that, although presenting itself before civilized peoples for the first time in the Caribbean Islands, some of its subsequent incursions extended far North, to Boston, even, to Philadelphia only seventeen years after its settlement, when it consisted mainly "of a few hundred families from the mother country clustered together" forming a small country town.

There is a great deal in the vast literature accumulated that bears upon the history of yellow fever; in perusing the many works relating to this part of the subject we are at once struck by the fact that at no time has the disease appeared or been suspected to appear in the tropical countries of the Orient; India, Indo-China, Southern China, Japan, the Philippine Islands seem to have escaped or have never had any epidemic disease that might be mistaken for yellow fever. This point is one that, in my opinion, deserves consideration and study, for inasmuch as the necessary climatic (heat) and entomologic (mosquitoes) conditions exist there, and the disease has not as yet been extirpated (and it will be very difficult to do so) from the other side of the Atlantic (West Africa), the danger of invasion of the Oriental countries will subsist, in a measure that is not generally appreciated. And worse still, the danger will be greater as exploration and commerce, by establishing new and more convenient (more rapid) means of communication between the countries surrounding the Great Desert and the western coast of the African continent, increase the chances of its transportation towards the Mediterranean and further east.

In looking for the origin of our American epidemics there is much matter that must be considered irrelevant; for instance, we can not believe that it was yellow fever that affected the tribes of New England, as reported, before the arrival of the Puritans, in which, according to tradition, they bled at the nose and became yellow, dying in such proportions that from 30,000 they dwindled to barely 300, for the disease thus vaguely described raged during the winter months; no more worthy of credit are the narratives extracted from Maya Indian records, carefully studied by Finlay and others, which might have been epidemics of malaria as well as yellow fever. A painstaking study of many documents dealing with this matter has led me to believe that yellow fever came to America from Africa, and that the western coast of that continent has been the natural abode of the disease. We have evidence of the comparatively mild character in which it appears among the Negroes, and only lately (from 1910), since it attacks the white inhabitants, has the question been properly investigated. From Africa it came to us with the slave trade, perhaps first to Barbadoes, as the records seem to show, spreading thence among the West Indies, and no doubt being periodically reinforced by new material brought with the slavers of the early days. My inference that it came from Africa is in relation with other diseases which also came with the Negro slaves but failed to spread in America because the "spreader" was not here, the means of

propagation was lacking; there are persons living in Cuba, for example, who remember having seen cases of sleeping sickness (trypanosomiasis) among the Negro slaves, who went on and died of the disease, here known as *modorra* or laziness. In some instances it was believed that the slaves assumed that condition purposely so as to die and "thus go back to their country." The absence of the tsetse fly precluded any possibility of the disease spreading in America.

And so we come to the first authentic epidemic among white people, in the island of Barbadoes, in 1647. In speaking of the disease during the following year, Du Tertre[1] says that "in the course of eighteen months it carried off one third of the inhabitants." All the islands bordering upon the Caribbean Sea, as well as the mainland (Panama, Darien), subsequently suffered epidemics of yellow fever, while in some of them the disease established itself definitely, raging during the summer, less active in winter, but continually demanding a fair number of victims from the population. The lines of trade, then gradually developing, brought the infection to Charleston, South Carolina, and the same year to Philadelphia, as noted above. The fever went further; during 1694 the city of Rochefort in France was invaded; two years before, a naval expedition intended for Canada, after visiting the island of Martinique, caught the disease and, arriving in Boston, June 17, reported having buried at sea 1,300 out of 2,100 sailors and 1,800 out of 2,400 soldiers! The "distemper" from the fleet extended to the city, causing the exodus of many families to the country until the infection disappeared.

The early nineteenth century was rich in epidemics of yellow fever, not only in America but in Europe as well. In 1804 it went as far as Leghorn, Italy, Lisbon, Portugal, and twenty-five cities of Spain were invaded. It also reappeared in New York, Philadelphia, New Haven and Providence.

In the United States, the South continued to suffer periodically until 1905 when the last epidemic occurred in New Orleans. The same happened in the Caribbean countries, in Brazil, Ecuador, Mexico, Cuba, etc. I refrain from setting here the calculated number of lives lost during the space of years herein recorded; aside from the fact that it would be inaccurate, as no records can be examined from the countries that suffered the most, the figures that I could guarantee as true ones are frightfully appalling.

This disease was particularly dreadful to the people because of the rapidity of its evolution. A person enjoying apparently perfect health will suddenly feel sick; headache, severe unto a sense of bursting, often accompanied by a slight chill; soon severe bone aches will rack the individual and the fever will make itself felt; at the end of 24 or 48 hours all symptoms may subside or suddenly grow worse, with uncontrollable vomiting, first of gastric juice or food, later streaked with blood or containing coffee ground matter. The kidneys become congested and later more seriously affected, sometimes to the extent of complete suppression of all function, thus rapidly leading to death. If there are no complications, cases are usually settled, one way or another, within six or eight days; if the heart, kidneys, lungs or liver were previously diseased, yellow fever often takes its toll in very short order; or if the attack is mild, even under those circumstances the convalescence is prolonged many days, sometimes leaving permanent lesions that in the end will shorten life. Thus in such a short period of time, under great pain, delirium, convulsions, perhaps, patients die in greater proportions than in most other infectious diseases. Some cases see their end in 24 to 48 hours, all the

[1] "Hist. Gen. des Antilles," p. 422.

symptoms piling up within that time. A constant sign of the disease and one that gives it its most common appellation is jaundice in greater or lesser degree and always more evident after death, when the glow of the blood circulation disappears from under the skin. Of course, there are many various types of the disease, which would be entirely out of place to describe here; we have only intended to show that its course is usually short, the symptoms prominent, severe and distressing and that death is too often all too rapid. When patients finally recover they remain immune for the rest of their lives.

As it may be readily surmised, during all those years ef repeated epidemics in various part of the Americas, the medical profession did not remain inactive; on the contrary, the most eminent clinicians were deeply concerned in the investigation of the causes that produced such dire results in their respective localities, and the theories advanced and the explanations presented filled the pages of both the scientific and the lay press. The old theory of miasms or effluviae was early thrashed over; the emanations from putrefying material, coffee that rotted at the docks in Philadelphia, was accused: it had been noted that the infection extended along the wharves, following the river shores; the foul sewers, where these existed, were also blamed for the "pestilence," "exhaling streams of unwholesome and poisonous gases." One thing was generally accepted by all who studied the epidemics—the influence of altitude. It was soon observed that the fever often invaded towns along the seashore or in flat lands and persistently kept away from even slight elevations, or when separated a comparatively short distance from the sea. This notwithstanding, during severe epidemics and exceptionally it has been known to extend beyond its usual limits to towns in the higher altitudes.

Beyond these facts, repeatedly corroborated, no real advance was made towards clearing up the epidemiology (manner of its spread) of yellow fever. In the last quarter of the last century, the science of bacteriology, thanks to the remarkable work of such men as Pasteur, Koch, Behring, etc., acquired great importance and worth in the hands of investigators the world over: the germs of the most dreaded infectious diseases were discovered (cholera, anthrax, tuberculosis, leprosy, diphtheria, typhoid, plague, etc.), and so there was great stimulus brought upon research of yellow fever. In Mexico, Brazil, Uruguay, Cuba and Ecuador, men thought they had found the cause of this disease, only to suffer disappointment in the end, for the germ or parasite of yellow fever has not been found as yet. Some of the claims were very hard to prove false, as the authors were men of high standing and profound scientific knowledge and training; such was the case with Sanarelli, an Italian bacteriologist working in South America, and with Noguchi, a Japanese savant, who mistook the cause of another disease (infectious jaundice) for that of yellow fever. Noguchi went to the extent of preparing a vaccine to prevent yellow fever and also a serum to cure the disease, both things, as we know now, perfectly useless. And it seemed an irony of fate, under the circumstances, that this great bacteriologist should lose his life through an attack of yellow fever in West Africa just as it was proved that his organism (his discovery) had nothing to do with his infection.

So far, although we know where and when the germ or parasite of yellow fever may be found, it has never been brought to light and therefore its appearance and its nature are still unknown. We know it is filterable, that it passes through the finest porcelain filters, and that it circulates in the blood until the third day of the disease and then can be detected only in the tissues

of some of the internal organs, so that when that blood or said tissue is inoculated into susceptible persons or monkeys they suffer an attack of the disease.

Until 1900 the quest for the cause of yellow fever had been entirely fruitless: the manner of its spreading was only conjectured and its prevention and treatment, therefore, a matter of hit or miss, in the hands of the most expert.

When the United States government took charge of the political administration of Cuba and Porto Rico, it soon established modern sanitary measures that brought down both the sick and the death rate, particularly in connection with the infectious diseases. Yellow fever, however, seemed to have been not at all affected, and the disease continued to collect its quota from the foreign population, Americans and Spaniards mainly, apparently in the same proportion as before. Here was an epidemic disease which, contrary to all expectations, refused to be put down by the same means that were successful as regards the other epidemics of beriberi, dysentery, typhoid fever, smallpox, etc. It was evident that a further study of its causes and the manner of its infection was necessary.

Major William Crawford Gorgas, who was later to acquire world-wide renown through his outstanding work in Panama, was the health officer of Havana, and General Leonard Wood (an army surgeon before the Spanish American War) was the military governor of the island.

The surgeon general of the army was George M. Sternberg, one of the most distinguished pioneers in the science of bacteriology, and he naturally gave much importance to the laboratory investigation of all diseases; he therefore appointed a board for the purpose of studying the infectious diseases of Cuba, with special reference to yellow fever. This board was composed of Major Walter Reed and Surgeons James Carroll, Jesse W. Lazear and the writer.

Work was begun on June 25, 1900, by distributing the necessary details among the several members, one man doing the post mortems of those who died, the other the bacteriologic work, planting of tissues and secretions of cases in an effort to isolate the germ, and the other the preservation and study of the organs obtained by autopsy. Major Reed, being the chairman, had no special work assigned to him; in fact, soon after the board convened, he had to leave for Washington so as to finish up the report upon "Typhoid Fever in the Army" which was being prepared in collaboration with Drs. Shakespear and Vaughn.

In the last days of June an epidemic of yellow fever developed in a city in the interior of the island, and in the first days of July, by autopsy of some cases supposed to have suffered from pernicious malarial fever, I discovered an epidemic of yellow fever among the soldiers of the garrison. It was at this epidemic that Major Reed and I first discussed the possibility of mosquito transmission, and upon our return to Havana it was unanimously decided to give the matter a thorough sifting.

The idea of the mosquito as a factor in the propagation of yellow fever was not new to us. Many years before (1699) Dr. Rush, of Philadelphia, remarked upon the excessive numbers of those insects at the time of the pestilence in that city; in 1848, Dr. Nott, of Mobile, Alabama, suggested that the yellow fever poison was disseminated by means of some insect "that remained very close to the ground." In 1854 Dr. L. D. Beauperthuy, French physician residing in Venezuela, published his ideas regarding yellow fever, holding that the disease was caused by the bites of mosquitoes; that it was not found where mosquitoes were scarce or absent; that it was produced by the same agents that brought about the intermittent

fevers; that the striped-legged mosquito was a domestic variety, etc. Believing very justly that yellow fever is not contagious, he could not think of man-to-man transmission; this was left to Dr. Carlos J. Finlay, a Cuban of English origin, who in 1881 gave his opinion that yellow fever was spread by the bites of mosquitoes "directly contaminated by stinging a yellow fever patient (or perhaps by contact with or feeding from his discharges)." Most unfortunately for his greater glory, Dr. Finlay was never able to convince any of his contemporaries, he could never produce a single experimental case of yellow fever, and although some of his cases at some time or other had abnormal temperatures, we know now, positively, that not one of those inoculated by him could have developed, as a result, an unquestionable attack of yellow fever. This failure in his part tended to discredit his theory which *in substance* was the correct one, though not exactly as he originally enunciated it.

Dr. Finlay was consulted when we decided to investigate his theories—a fact that naturally gratified him greatly. He gave us some mosquito eggs which subsequently hatched, the insects finally dying without causing any harm; he told us of his ingenious methods of infecting the insects, which we followed for some time and subsequently abandoned for better ones.

In many previous writings I have gone extensively into the detailed work of the Army Board and I shall therefore only briefly sketch it here, since we are principally interested in the results.

Upon obtaining a sufficient number of the mosquitoes, the three working members of the board (Carroll, Agramonte and Lazear) devoted their time to breeding them and infecting them by feeding them upon yellow fever cases at the hospital, later applying them to themselves and to whoever was willing to run the risk of getting the disease in that way, then considered remotely possible only. One day Carroll was so unlucky as to let an infected mosquito bite him, inadvertently, thereby developing the first case of experimental yellow fever. Soon after, in fact, during Carroll's illness, the same mosquito and others were applied to a soldier who consented to the operation, and he later developed an attack of yellow fever, thus proving beyond a doubt the mosquito transmission of the disease. While Major Reed, still in Washington, was preparing to join us, Dr. Lazear became infected at the yellow fever hospital and died on September 25, 1900. The sacrifice of his promising life was a serious blow to the board, but as soon as Carroll completely recovered, Major Reed having returned from the United States, the experiments were renewed at a small camp (called Camp Lazear) established for the purpose.

Eighteen experimental cases were produced with mosquitoes, by blood injection and by the use of filtrated serum from yellow fever patients, *without a single death.*

Besides this, by having several men living for 20 days in contact with soiled linen, clothes and bedding from yellow fever cases, it was shown that the disease is not produced that way.

The names of John R. Kissinger, John J. Moran and Dr. Robert P. Cooke deserve special mention, inasmuch as they offered themselves as subjects for the experiments, without remuneration whatsoever.

As a result of its work, the Army Board made the following discoveries:

1. Yellow fever is transmitted in nature solely by the bites of mosquitoes; soiled articles (called fomites) being inoffensive.
2. Stegomyia (now Aedes) mosquitoes become infected when they bite a yellow fever patient within the first three days of the disease and not later.
3. Mosquitoes can transmit the disease only after 10 to 12 days of feeding from a yel-

low fever patient and not before, retaining the power to infect during the rest of their lives.

4. The period of incubation (from the mosquito's bite to the first symptom of the disease) does not extend beyond six days.
5. The germ of the disease, still unknown, exists in the blood of cases and in the serum, even after filtering, during the first three days of the disease.

These facts have been repeatedly corroborated and, based upon them, all the successful campaigns against yellow fever have been carried out, extirpating the disease from Cuba, Mexico, Ecuador and the United States. It was also apparently eradicated from Brazil, but during the last two years very evident epidemics have cropped up there, causing justified alarm to other countries. The construction of the Panama Canal under the sanitary control of Colonel Gorgas was possible only because he applied the measures derived from the Army Board's findings.

Within the last three years it has been discovered, by working parties from the Rockefeller Foundation, that certain Asiatic monkeys (*M. rhesus*) are susceptible to yellow fever, so that now it is no longer necessary to resort to human subjects for all kinds of experiments that are being tried out in an effort to elucidate the causative germ and certain qualities of the virus (poison) of the disease. These experiments have brought out many interesting facts with relation to the origin and the spread of yellow fever; for instance, it has been possible to infect the special kind of monkeys by just rubbing the virus upon their skin; also by the bites of mosquitoes of other varieties of the same family, not previously tested for lack of subjects; also that the virus may be kept for many days, under certain conditions, without losing its infective power, etc. But nothing so far obtained can be said to have been of any practical value, that is, of value in preventing or curing the disease, and all measures to-day, after 30 years, must be based upon the discoveries of the Army Board in 1900–01.

It is possible, however, that in the near future the injection of convalescent monkey serum may be found useful in offsetting an attack of the disease, and all those in contact with it or working in the laboratory should be protected in that manner. In the treatment of the disease, large massive doses of the same serum are likely to prove beneficial, but there is much clinical and experimental work to be done before these points are made sufficiently clear.

To-day we must rest content in the fact that in civilized communities yellow fever should not be held in fear; its elimination is a matter of few days after its discovery, if attention is directed intelligently and persistently towards the destruction of mosquitoes (by fumigation) and their breeding places (by suppressing all water containers liable to receive their eggs, by proper drainage and continued vigilance), since the patients themselves are of secondary consideration.

In Panama, Cuba and the United States the menace of yellow fever is no longer cause for worry or alarm since the sanitary authorities are ever on the alert and have demonstrated that they can successfully cope with it. In Brazil the work of sanitation is much hampered by the racial conditions of the people, the difficulty in educating the population so as to cooperate with the health authorities. The same handicap is found in all wild or semi-civilized states, and they are the ones that are keeping up the infection in the form of endemic, continuous, yellow fever cases. At present the fever can be found only in West Africa and Brazil, the disease having disappeared from all its formerly well-known centers or foci.

FINALITY IN MATHEMATICS

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THE number of the developments which seem to have reached their final stages appears to be relatively larger in mathematics than in the other broad scientific subjects. For example, the formulation and the proof of the Pythagorean theorem as found in Euclid's "Elements" are still satisfying and inspiring. The various extensions of this theorem and the numerous proofs thereof are evidences of its important connections with other mathematical developments, and in this direction there is no indication of finality, but those who are satisfied with the theorem itself and a single proof thereof may see in Euclid's presentation a final accomplishment. This presentation seems to represent a culmination of efforts extending through more than a thousand years as may be inferred from the wide-spread appearances of the so-called Pythagorean triads and the recently discovered uses of the theorem even by the ancient Babylonians.[1]

Text-books have contributed powerfully towards finality of results in elementary mathematics since they tend to establish a kind of intellectual currency with respect to results which are commonly regarded as fundamental. There are various obvious similarities between intellectual currencies and financial currencies. In both cases standard forms are commonly accepted at their face values without considering the real underlying foundations. One wide difference between these currencies is that while every one has the right to try to originate intellectual currencies the various governments usually reserve for themselves the right to originate their own financial currencies. The establishment of the intellectual currencies is one of the most important and also one of the most complex activities of human society, resulting from diverse and multitudinous contributions of very unequal values. In fact, changes here are sometimes so gradual as to become tangible only when periods separated by long intervals are considered.

The question of finality is especially interesting in connection with the great scientific production of our times. If it could be assumed that the majority of the new results which are being announced are in their final forms, the magnitude of the task of future investigators to become familiar with the earlier attainments would appear to be almost appalling, especially in a subject like mathematics where connectivity has always been emphasized. On the other hand, if it can be assumed that the bulk of this production represents an intermediate stage of developments which can later be viewed from a simpler and much more general point of view one can look forward to the future investigators with a much greater complacency of mind. Various early developments in mathematics tend to inspire this complacency notwithstanding the fact that brief historical statements relating thereto are often misleading.

In particular, it is often stated that R. Descartes invented analytic geometry, but developments along this line were neither inaugurated nor extended to their final stages by R. Descartes. One of the profoundest facts of the history of mathematics is that geometry and algebra seem to have influenced the

[1] *Cf.* O. Neugebauer, *Quellen und Studien*, 1: 81, 1929.

development of each other since the beginning of mathematical records. In particular, it is commonly agreed that in the second book of Euclid's "Elements" we find a kind of geometric algebra, while some geometric problems were solved algebraically by F. Vieta, and he has often been regarded as the founder of algebraic geometry. From this point of view developments in geometric algebra as well as in algebraic geometry preceded the times of R. Descartes. On the other hand, the development of most of the standard forms of our modern analytic geometry, such as the usual forms of the equations of the tangent lines of the conic sections, appeared long after the times of R. Descartes.

Even as regards rectilinear coordinates, which are commonly called Cartesian in honor of R. Descartes, he was far from the modern general views. In particular, he never used negative abscissas. If our modern students of analytic geometry were not allowed the use of negative abscissas they would find themselves greatly hampered, and if R. Descartes could take one of our modern final examinations closing a first course in analytic geometry, with all the knowledge he possessed relating thereto while living, it is likely that most of our instructors would be inclined to flunk him. This statement is not intended to detract from his great mathematical abilities and deep insight, but it aims to convey a correct impression of some of the limitations of his actual knowledge along the lines whose development he influenced profoundly.

The work of R. Descartes in analytic geometry is conspicuous for its lack of finality. Such a fundamental statement as the one that every equation of the first degree in two variables represents a straight line and that every straight line may be represented by such an equation does not appear explicitly therein. On the contrary, such apparently final statements are usually especially emphasized in our modern works on this subject. At the close of his "La Géométrie" R. Descartes stated that he hoped that posterity would be grateful to him not only for the things which he explained but also for those which he omitted voluntarily in order to give others the pleasure of discovering them. Our modern tendency, on the contrary, is to deal with finalities in treating a mathematical question. While the congruence of two triangles having two sides and an angle opposite one of these sides respectively equal does not seem to have been considered before the beginning of the eighteenth century we now lay considerable stress thereon in our works on elementary geometry for the sake of greater completeness.

Even in such a comparatively new subject as the theory of groups there are many instances of finality. For example, A. Cayley proved as early as 1854 that there are two and only two abstract groups of order 6 as well as two and only two such groups of order 4. These are obviously final results although the methods of proof may be altered. As regards the former of these results it may be of interest to note here that twenty-four years after publishing it A. Cayley published an article in the first volume of the *American Journal of Mathematics* in which he stated that there are three groups of order 6. The fact that this error seems to have been overlooked by the editors of this periodical, as well as by A. Cayley himself when his "Collected Works" began to be published under his personal supervision at a much later period, is a very striking instance of the fact that the most obvious truths are frequently overlooked by those interested mainly in far-reaching generalities.

While many problems in mathematics are being finally solved there are others of long standing which still await solu-

tion. In fact, when a problem is finally solved it frequently points to a related one which can not be solved at the present time. As an instance of this kind it may be noted that while it is easy to determine all the groups of orders 4 and 6 noted in the preceding paragraph it is not yet possible to determine all the groups of the general order g. It has recently been shown that the number of the distinct groups whose orders are less than 100 exceeds 1,000, and the complexity of this determination increases so rapidly with the number of factors in the order that there seems little hope at present that this problem will be completely solved in the near future. Judging from the past, it appears that the number of the problems which await solution will increase with the number of those which are finally solved so that the problem of the complete mastery of mathematics is becoming continually a more hopeless one notwithstanding the encouraging increase in the number of final solutions and their growing generality.

In view of the fact that the text-books on elementary mathematics are largely concerned with material which seems to have reached its final form as regards simplicity of statement it might at first appear likely that the final text-books on certain subjects should have been reached. On the contrary, the activity in text-book production seems to be on the increase, and while some new text-books are regarded by the public as no better and no worse than their predecessors, there is frequently a decided claim therein as regards improvement. While these claims may sometimes be due to misconceptions on the part of their authors it is likely that the present text-books on elementary mathematics meet actual conditions better than those which were prepared half a century ago. At least, the final text-book on an elementary mathematical subject seems to be unlikely to appear under the present conditions relating to the adoption of such works for class use leading often to very unwise changes.

While the mathematician seems to have no good reasons for assuming finality as regards the developments in the entire field of his subject he is constantly encouraged by what appears to be permanent progress along special lines. In some fields the feasible advances are governed somewhat by practical applications. For instance, the extent of the tables of logarithms has been largely determined by the degree of accuracy attained in measurements. In more recent times the determination of all the abstract groups of given low orders has been affected by the supposed usefulness of these groups in the general theories as well as in hope that use could be made of them in certain fields of applied mathematics. Mathematical investigators are, however, more commonly governed by the desire to secure greater harmony in the developments known to them than by the hope that their results may become useful. Here our esthetic nature furnishes the main motives and practical applications have but little influence. In this direction finality seems to be as much out of the question as finality in music.

In recent years a large amount of source material relating to the history of mathematics has been collected, and such material is frequently final as regards the particular sources in question. On the other hand, historical statements based thereon are apt to be greatly affected by new discoveries relating to the subject. For instance, the opening sentence under the heading "Mathematical Societies and Periodicals" in the fourteenth edition of the Encyclopaedia Britannica is as follows: "The number of mathematical societies, clubs and circles organized since the early one at Hamburg in 1690 is exceedingly large,

but the number of mathematical periodicals since the seventeenth century is very much larger." It is obviously much easier to secure information in regard to the mathematical periodicals which were soon discontinued than in regard to the mathematical clubs which were soon abandoned. Hence it would appear possible that the quotation under consideration might be affected by later discoveries and more complete enumerations along these lines.

Those who are not familiar with the recent activities in the history of mathematics might be inclined to think that the history of ancient mathematics had reached a stage of finality, but it is just along these lines that some of the most striking and revolutionary announcements have recently been made. The recent publication of a translation of the "Rhind Mathematical Papyrus" by A. B. Chace, of Brown University, is evidence of renewed interest along this line in our own land, and the periodical to which we referred at the close of the first paragraph is largely devoted to recent developments relating to very ancient mathematics. For instance, it is stated on page 80 of this periodical that the ancient Babylonians possessed a complete formula for the general solution of the quadratic equation. Their restricted knowledge of numbers made it impossible for them to use this formula in all cases. Serious misstatements relating to the attainments of ancient mathematicians have often resulted from a failure to discriminate between the special use of a rule which is equivalent to a general modern formula and the extension of the number concept so as to make this use always possible. In the case of the quadratic equation thousands of years seem to have elapsed between these two stages.

Finality is probably one of the most powerful incentives for the mathematical investigator since it dignifies the object of his investigation enormously when he feels that his results will be final as well as enduring. As a matter of fact, however, the element of finality is apt to be only transitory since new possibilities for advancement are likely to appear even before the goal in view is reached. On the other hand, while vistas of further desirable advances may present themselves there usually is a sense of enduring progress attained and of special elements of finality in the form of theories or methods which are sufficient to incite to a repetition of effort. Thus mathematical progress seems to have been made with great variations in speed and in the utilization of earlier attainment for thousands of years but never before with such an amazingly growing number of participants as during the last century. This great augmentation of efforts tends to exhibit increasing resources rather than finality as regards possible advances.

DIFFUSION, OSMOSIS AND OSMOTIC PRESSURE

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WHAT is the reason that an odor spreads so rapidly through even the still air of a room? How is it that the oxygen of the air gets into the blood, and the carbon dioxide gets out, even though there are continuous membranes between? Why are wilting flowers, celery or salad plants revived by being placed in water? Why or *how* does sap rise in a plant?

Then there is the question as to the particular manner in which the digested food gets into the blood stream, and from the blood vessels to the tissues where it is needed. At other points of the body certain portions of the blood are being separated out as secretions. How? It is not simply a question of soaking through a leaky wall, as water soaks through a towel. At any particular point certain substances only are passed through, others are held back to be passed through apparently the same kind of a partition somewhere else.

When a piece of fresh meat is placed in salt, the fibers soon become shriveled and hard from the loss of the juices, which go to liquefy the salt. But the water may pass *in* through the same kind of a membrane with equal ease in other circumstances. Oysters are "fattened" by being placed in a vat of fresh water.

Fresh fruits in a thick sugar syrup and dried fruits in fresh water show exactly the same behavior, losing water in the first case, gaining water in the second. It seems to be merely a case of the passage of water from a region where it is plentiful to where it is not. But what is the mechanism of the exchange through the partition?

If I pour an ounce of bird-shot into a box, they roll down into the lowest corner and stay there. But if I put an ounce of gas into an empty room, immediately it expands to "fill" the entire space. How is it done? As suggested in the opening sentence, the action is similar when other gases are present in the room. The action is merely slowed up, but the mixing proceeds. How does it come that the gases of the atmosphere are uniformly mixed together, and not stratified according to density, as a mixture of bird-shot and sawdust would be if shaken up together?

Last week I put a few crystals of copper sulphate in the bottom of this tall jar, and covered them with water. The blue color of the water in the bottom of the jar indicates that solution has already begun, and the heavy copper sulphate has risen against the force of gravity. Next week it will be higher, next month higher still, and so on until there is as much of the blue color at the top as at the bottom of the jar. It may take a long time, but the tendency of the copper sulphate to go from where it is to where it isn't is just as evident as in the case of the lighter liquids and gases already mentioned. How does it do it? For that matter, how does any solid dissolve?

We shall get a vivid picture that connects all these apparently unrelated phenomena if we accept the kinetic molecular phenomena of matter, according to which all matter is made up of small particles (molecules), each one going as fast and as far as it can, *i.e.*, until it strikes something. The mean velocity of the molecule (or rather the mean square of the velocity) is a measure of the temperature; all the above

phenomena are accelerated by a rise in the temperature. The total kinetic energy of the moving particles ($\frac{1}{2}$ Nmv^2, where N is the total number, m the mass of each molecule and v^2 the mean square of the velocity) constitutes the heat energy of the body. It follows that if two gases are at the same temperature (have the same kinetic energy) the molecules of the lighter gas have the greater velocity. In fact, the molecular weights are found to be inversely proportional to the squares of the rates at which they diffuse through a porous partition. *E.g.,* oxygen molecules are sixteen times as heavy as those of hydrogen, hence the latter should work their way through small openings four times as fast as the former. Here is a little inverted cylinder of unglazed porcelain, closed by a rubber cap. From the cap a glass tube twelve or thirteen inches long extends downward into a vessel of water. Now I will bring down over this cylinder an inverted beaker and pass up into this a stream of illuminating gas consisting mostly of hydrogen and another light gas, carbon monoxide. Almost immediately, bubbles appear at the opening of the tube, showing that more gas must be passing into the cylinder than is passing out. Now I remove the beaker with its atmosphere of lighter gas, and the bubbling stops. Soon the water begins to rise in the tube, showing a diminution of pressure inside the cylinder to less than atmospheric. The movement in both cases depends on the relative amounts of hydrogen and air on the two sides of the partition. When there was more hydrogen outside, the balance of exchange was *in;* when the hydrogen inside had accumulated and there was none outside, because the beaker was removed, the outward flow predominated. It mattered not that at the beginning the total pressure inside was equal to that outside; to the hydrogen molecules, the space inside was empty—the *partial* pressure of the hydrogen there was zero—and the presence of other molecules, like the presence of the aborigines before our Pilgrim fathers, was only a temporary hindrance. Immigration of the hydrogen molecules would have gone on until hydrogen concentration on one side of the partition was equal to that on the other.

The kinetic molecule theory offers so perfect an explanation (*i.e.,* mechanical picture) of this experiment that we have no hesitation in applying it with equal confidence to all the other cases mentioned above, and with equal success. But the theory does not rest upon this sort of proof. If we imagine an elastic box containing an immense number of tiny elastic spheres, bouncing about and hitting the sides of the box and each other, and then apply the most rigid mathematical laws to the results of their behavior we shall find that (1) They will exert a uniform pressure on the sides of the box (just like a gas).

(2) If the volume of the box be increased, they will immediately occupy the additional space, but the pressure will be diminished (just as in the case of the gas).

(3) The product of the pressure and the volume will be a constant quantity (just as in the case of a gas—Boyle's law).

(4) This constant is two thirds the total molecular kinetic energy of the system, or $PV = \frac{2}{3} \times \frac{1}{2} Nmv^2$. (The pressure of a gas multiplied by any change of volume it may undergo is the amount of work done *by* or *on* the gas. This equation has been of immense importance in thermodynamics. The fact that it has not been found wanting in spite of so many demands made upon it indicates that it must be founded on something fundamentally true.)

(5) If we make the further assumption that these tiny elastic balls have an attraction for each other, also that they must occupy some space (have volume),

we find it necessary to introduce certain modifications that convert PV = K into Van der Waal's equation, an expression that describes the behavior of a real gas over a much greater range of conditions than Boyle's law can.

(6) If we imagine the velocity of the particles to be increased, the pressure will be increased in proportion to the square of the velocity. (Charles' law for gases: "Pressure varies as absolute temperature." Remember that the velocity squared is proportional to the temperature.)

In spite of this strong evidence of the probable correctness of our modern view of matter, there remains the skeptic's final retort, "Show me a molecule and I will believe." We may as well admit that this is quite out of the question for the vast majority of the molecules, for they are all smaller than half the wave-length of light (say from perhaps 5 μμ down to 0.2 μμ, while light-waves run from 390 μμ to 700 μμ. A millimicron is about 4 ten-millionths of an inch). But particles much smaller than the smallest visible under even the best microscope made, far too small to *reflect* waves of light that can form an image, may, if illuminated transversely, and with a dark background, *diffract* the light and appear as bright points. Dust motes floating in a beam of light shining through an otherwise dark room or a searchlight shining through a fog illustrate exactly what I mean. Complicated methods have been devised for measuring the diameters of these particles, and it has been found that the smallest visible in this way run down pretty close to some molecular dimensions, though we may as well admit that they are thousands of times larger than such molecules as the simpler gases.

But now glance through this low-powered microscope (10x) if you wish to see what I am talking about. Under the lens is a little chamber into which I have drawn a whiff of smoke. It is illuminated by a tiny lamp off at one side, the light of which is condensed into a cone (Tyndall's cone) directly at the focus of vision. Without the microscope you see merely the phenomenon described above. But through the microscope you see a multitude of little stars drifting about, appearing and disappearing as they rise above or fall below the focal plane. But also you notice something else. Every one of these points is aquiver with a motion too rapid for the eyes to follow; all we can distinguish is the fact that there is continual motion. From the name of the botanist Brown who first saw these motions they are called Brownian movements. He thought for a long time that the motions indicated life in the particles, but we now have a better explanation.

Go back to the kinetic molecular theory; recall the dance of the molecules, and the thumping every surface is continually receiving from them. For the smallest visible particle, there will be thousands of blows per second, coming from all directions, but *on the average,* as many from one direction as from another, so that they cancel out, and the body feels a uniform pressure on all sides. But when we get down to particles as small as these we are looking at, the blows on one side in any instant may very likely exceed those on the other side by enough to give the particle a distinct shove. It is this continual knocking about due to the rain of blows from the molecules that you are now observing. In other words, the particle of smoke is so near the size of the molecular Romans surrounding it that it does as the Romans do. In fact, we may call it a huge molecule, and we have here ocular demonstration of the kinetic molecular theory.

I can not tell you here how rigidly this phenomenon has been subjected to mathematical analysis, or how com-

pletely it has stood up under tests; simply that we are, by this time, as thoroughly convinced of the existence and the behavior of molecules as we are of the swarming aggregates of molecules that jostle us on State Street at five o'clock. The rapidity of expansion of gas into an empty space is an indication of the rapidity of movement of the molecules. As may easily be shown from the gas equation, $PV = \frac{1}{3} Nmv^2$, the lightest molecule, that of hydrogen, has an average speed of a mile a second or more at the freezing-point of water. That diffusion takes place more slowly when matter is already present is to be expected, but that it takes place at all under these conditions is proof that not all the space is occupied by the molecules. Comparatively speaking, there is more space, on the average, between the molecules of air than there is between the earth and the moon, for while the distance to the moon is only thirty times the earth's diameter, the average distance between the molecules of air is about one hundred diameters of the molecules. In the case of liquids, not more than 75 per cent. is empty space, so diffusion is still slower. The molecules of solids are not much closer together than the molecules of liquids, but there are forces acting here that we scarcely find a trace of in the case of liquids, which slow up molecular motion still more. But that it is still present is shown by the fact that a bar of lead, resting on a plate of gold for a year or so, was found to have more gold in it than was found when the experiment began.

Let us return to our solution of copper sulphate. We see the progress of the copper sulphate into the pure water, but we do not see that the pure water is also passing into the region occupied by the solution. Water molecules are passing in all directions, of course, but the presence of the copper sulphate has "diluted" the water—reduced its concentration in other words—so that there is a *stronger* water current towards the solution than away from it, and this will continue to be the case until the copper sulphate and the water are thoroughly mixed all over the space occupied by them. If we want to make this current of pure water toward the space occupied by the solution evident, it will be necessary to hold back the molecules of the solute. This I have done in this osmosis cell, ready made for me by mother nature. I have scooped out the inside of this carrot, filled the hollow with a strong sugar solution and stopped it up with a cork. A glass tube passes through the cork into the solution. The carrot is then placed in a dish of pure water. In a very little while, the rise of the liquid in the tube indicates that pure water is passing *in* more rapidly than the sugar molecules are able to pass *out*. In fact, we have duplicated with liquids of different densities our experiment with the gases of different-sized molecules and the porous cup, and made visible what is taking place in every living plant all summer long. The root hairs are bathed in a dilute nutrient solution of mineral salts. Within the cells of the plant is a more concentrated solution—concentrated because of the continual evaporation taking place through the leaves and because of the building up of large molecules of starch and sugar out of water molecules and carbon dioxide from the air.

The white corpuscles of the blood are simple cells floating in the blood serum which is, essentially, a 0.9 per cent. salt solution carrying a host of other things in suspension. The water can pass through the walls of the corpuscle quite freely, the salt very slowly, but the protoplasm inside the cell can not pass out; in other words, we have here a cell with semi-permeable walls. As far as the salt is concerned, the cell contents and the surrounding serum are of equal concentrations; we speak of them as being

isotonic. If the cell be placed in a slightly stronger salt solution, water passes out more rapidly than it can pass in, and the cell shrinks and becomes wrinkled; if it be placed in a weaker solution, it loses salt, absorbs water, swells and bursts. Distilled water causes similar action when taken into the body. It has "taste"; it dissolves so much from the epithelial cells of the mouth that the taste nerves rebel. There is a spring in southern France known as the Poison Spring, but it contains no poison—the water is purer than the ordinary distilled water. The extraction of sugar from the sliced beet is not a mere washing out of the sugar, as dirt is washed from clothes; the sugar diffuses through the cell walls as molecules. Beets must not be crushed, as one crushes cane, for crushing the cells would release obnoxious compounds that could not later be got rid of. Fortunately, the cell walls are impermeable to them. An interesting physiological experiment may be mentioned here.[1] If the uterus of a guinea-pig be suspended in an isotonic saline solution (0.9 per cent.) certain drugs will cause it to contract. If the salinity of the surrounding liquid be increased, the effect of the drug is diminished, stopping entirely at a concentration of 1.3 per cent.; but, in a weaker solution, the action of the drug is increased. In the stronger solution, the currents are from the cell *out;* in the weaker solution, the currents are *in,* hindering the absorption of the drug in one case, helping it in the other. A dose of bicarbonate to remedy the acidity of the stomach is taken with a little water; the action takes place outside the cell. But if a drug is to be absorbed by the cells, take much water, so as to decrease the tonicity of the fluids in the digestive tract and set up a current *into* the cell, which will carry the drug along with it. Some drugs, such as magnesium sulphate, are not absorbed by the cell walls; we say the cell walls are impermeable to them. To dilute the contents of the intestines, an abundant secretion is poured forth from the walls. This explains the laxative effects of Epsom salts.[2] The loss of water by a cell increases the concentration of its contents, and mass action may accelerate chemical processes within the cell that would take place very slowly or not at all under ordinary conditions.[3] This passage of molecules through a membrane impermeable to other molecules that may be present is called *osmosis,* a term we shall find convenient.

Suppose that our tube, in the carrot experiment, had been bent at right angles. We should then have had a very fair imitation of an excretory gland in action. Of course, the action would have stopped as soon as the sugar had been washed out of the cavity and the liquid inside had become of the same concentration as that outside. Or it might be that the cell could build up, out of the small molecules that could enter from the outside, larger molecules to which the cell membrane was not permeable. ("Larger" or at any rate *different.* It is not always a matter of size that determines whether or not a molecule shall pass through a certain membrane.) Now if the other end of the cell is open, or closed by a membrane permeable to these new molecules, we shall have a steady current through the cell, and a model of a secretory gland, such as the salivary or pancreatic.[4]

A semi-permeable membrane is not absolutely necessary for the demonstration of osmosis. If alternate drops of solutions of higher and lower tonicity be placed in a capillary tube, and the lengths carefully measured, it will be found that the more concentrated will become longer at the expense of the less concentrated. The surface of the liquids

[1] Bayliss, "Physiology," p. 163.

[2] Findlay, p. 53.

[3] Bayliss, p. 63.

[4] Bayliss, p. 334.

serves as the semi-permeable membrane. Two beakers, one filled with pure water, the other with a salt solution, if placed under a bell jar, will exhibit the same phenomenon, water distilling over from the pure water to the solution.

To return to our carrot experiment. As the column of liquid rises higher and higher in the tube, it is evident that there must be a strong pressure exerted on the inside of the cavity, or "cell." This has been named osmotic pressure, since it seems to be caused by osmosis (passing through) of the water molecules into the cell faster than they can pass out. But this, in turn, is due to the fact that the sugar molecules diluted the water (reduced the concentration) so that not as many molecules of water per second struck against the inside of the cell as against the outside—per square centimeter, of course. When equilibrium has been attained, if the cell is strong enough to stand such a pressure, as many molecules will strike from one side as the other, so the net water pressure will be zero, and the extra internal pressure will be due to the sugar molecules bombarding the cell walls, trying to get out but unable to. Haldane[5] defines osmotic pressure as the pressure of the water outside the cell, but in this he is in disagreement with the majority of physicists. It is a mere matter of nomenclature anyway; there is no disagreement as to the amount or the meaning of the pressure itself.

It is thus seen that osmotic pressure is due to the same thing that brings about solution pressure of a dissolving solid or vapor tension of an evaporating liquid or the gaseous pressure of a permanent gas. And that is the motion of the molecules. The pressure is not caused by the membrane any more than atmospheric pressure is caused by the barometer, but to make manifest and to measure the pressure we have to keep the solute from streaming into an unoccupied region, just as we measure atmospheric pressure only by preventing the air from streaming into a vacuum.

[5] Rogers' "Physiology," p. 42.

When we come to measure this osmotic pressure we run across some surprising relations. Measurement is made by allowing the water to rise as far as it will in a vertical tube attached to a cell containing the solution, and measuring the hydrostatic pressure, or by increasing the pressure within the cell by means of a manometer until the inflow of water from the outside is prevented. This is the better way, since the concentration of the solution is not changed.

Let us make a solution of sugar, 15.3 gms per liter (about a heaping teaspoonful to a quart of water). It will exert a pressure equal to atmospheric. So also would 0.0893 gms of hydrogen if confined in an equal space. But 15.3 is 171 times this weight of hydrogen and the molecular weight of sugar is also 171 times the molecular weight of hydrogen so there must be equal numbers of sugar molecules and hydrogen molecules. In other words, we have equimolecular concentrations producing identical pressures. Does it not suggest that they are in the same condition, the gaseous?

If we change the volume of the solution in which we have our 15.3 gms of sugar, we change the pressure in the inverse proportion. But this is nothing but Boyle's law which, we have seen, describes one of the most characteristic properties of gases. Or if we change the amount of sugar dissolved in one liter of water, the pressure changes in the same proportion. If we dissolve equimolecular quantities of other substances in one liter of water we get exactly the same pressure, always providing, of course, that (as often *is* the case) there is no reaction between the water and the solute that changes the number of particles in solution. Here we have Avogadro's law for gases—that equal numbers of molecules in the same vol-

ume exert the same pressure at the same temperature. If, keeping the concentration the same, we measure the osmotic pressure of a solution at zero and again at one degree above zero we find that it has been increased by one two-hundred-seventy-third. Here we have Charles' law for gases.[6]

We have mentioned the modification of Boyle's law (Van der Waal's) made necessary by the attraction of the molecules for each other, and the fact that the molecules themselves must occupy some of the space in which they are moving about.

In the case of solutions, slight deviations from the laws mentioned in the last paragraph can be shown to fall into an orderly scheme if we make due allowance for these factors and a few others that would naturally be of much more importance in solutions than in gases. (Thus a sugar solution seems to act as if each molecule of sugar were associated with five water molecules.) We can not entirely neglect the influence of the membrane or the electric charge it may carry. This will be discussed later. Membranes are colloids, and little is known yet as to what might be expected of their behavior. But when we ascribe numerical values to such of these factors as is possible we get an equation of the same form as Van der Waal's.[7]

Fortunately we are not obliged to depend upon an actual measurement of osmotic pressure in comparing the tonicity of different solutions. It is a difficult operation. But theoretical considerations showing that the boiling-point, which is only the temperature at which the vapor pressure becomes equal to the atmospheric, is dependent upon the osmotic pressure are borne out by experiment. We have already pointed out that the surface of a liquid may be looked upon as a semi-permeable membrane. Evaporation is merely the passing through this membrane of those molecules that have sufficient kinetic energy to overcome the backward pull of the other molecules in the body of the liquid. If there are molecules of another substance present, too large or too heavy to break away, they are taking the place of just that number of molecules of the solvent which might be passing out through the surface. In order to make up for this, the temperature must be raised, increasing the average kinetic energy of all the molecules, until the same number of molecules are able to leave as before. As a matter of fact, one gram molecule of any non-volatile substance will raise the boiling-point of water 0.52°. This rise of the boiling-point varies with the solvent, being generally more for other solvents than it is for water.[8]

Similar considerations apply to the separation of the pure solvent from a solution by freezing. The surface of the crystal acts like a semi-permeable membrane. In this case, only those molecules with less than a certain minimum of kinetic energy adhere to the surface of the crystal and give up their heat of solidification to the main body of the liquid. When another sort of molecule is present which can not crystallize, the temperature must fall (average kinetic energy must decrease) until the same proportion of the total number of molecules is below the freezing temperature as in the case of the freezing of the pure solvent. The depression of the freezing-point for a gram-molecular solution in water is 1.84° Centigrade. Determinations of the freezing-point and the boiling-point of various solutions are constantly being made by the chemist in the measurement of molecular weight, or, in other words, in learning the comparative numbers of particles that function as molecules in a solution. Such determinations are easy and accurate.

6 Haldane, *Biochem. J.*, 12: 464, 1918.

7 Bayliss, pp. 150, 152, and Rogers' "Text-Book of Comparative Physiology," p. 48.

8 Morgan, "Elements of Physical Chemistry," p. 191.

The electrical condition of the membrane as affecting osmosis has been referred to. It must be due to this that many membranes have been found to transmit ions of one kind but not of another. For instance, the stomach walls seem to be permeable to the positive ions Na and H, but not to the negative ions Cl and HCO_3. Only if the food contains NaCl is HCl to be found in the stomach,[9] its presence being explained as follows: The NaCl dissociates into positive Na ions and negative Cl ions, the former diffusing through the walls of the stomach into the blood stream only as fast as they are replaced by the positive H ions from the blood. The latter arise from the dissociation of the carbonic acid in the blood, and this comes from the CO_2 thrown into the blood as the result of the general oxidation processes of the body. Actually the acid never accumulates in the blood, for this reason among others that the sodium ions unite with it to give $NaHCo_3$, a salt with an alkaline reaction.

Not always is osmosis through animal membrane so easily explained as this, however. The walls of the blood cells are permeable to both H and Cl ions, impermeable to Na and HCO_3 ions. One might be inclined to say it was a question of weight, but the skin of the frog allows Na ions to pass out, but not in, while K and Cl ions may pass either way. Probably no single explanation is sufficient.

Fertilization of the ovum by the sperm-cell is accompanied by changes in the permeability of the wall, and part of Loeb's success in artificial parthenogenesis was due to his discovery of the salt solutions that had the correct osmotic pressure to stimulate natural conditions. Not only in the life history of the cell but even in its very beginning we find osmosis playing a very necessary part.

One thing more remains to be said. Recalling that PV has the dimensions of work, it is evident that any change in the osmotic pressure within a cell implies that work is being done, either by or on the system. This can be calculated from the well-known expression for the work done by a gas when its volume is changing isothermally from V_1 to V_2 $(=dV)$, $W=PdV=RT \log_e (V_1/V)$, T being the absolute temperature and R a constant depending on the units used. For instance, the kidneys separate from the blood a liquid of much higher osmotic pressure than the blood itself. Incidentally, we may note that the kidneys seem to be the regulators of the osmotic pressure of the blood. Whereas it is usually about 0.3 molar, extirpation of both kidneys may run it up to five or six times that amount. But the osmotic pressure of the urea and salt in the kidneys is about molar. That is, the concentration has been about tripled. From the above equation, it is easy to calculate the amount of work that the kidneys must do on the contents of the glomerules in order to keep up the excretion of the urine. Where this energy comes from and how it is applied to the job in hand is pretty hard to understand. There can be no disputing the fact that it is being done. To shut our eyes to the fact is equivalent to being uninterested when we see water flowing uphill.

We may close by calling attention to the fact that changes of concentration (changes of osmotic pressure) within the cell may take place by the splitting of large molecules into smaller ones, or the reverse. In the latter case, the number of molecules being less, the osmotic pressure is lessened, and the result is that energy is set free to be used in the various processes of the body needing energy. Doubtless a more thorough study of the osmotic pressure of various cells of the body will go far toward solving the mystery of how the body utilizes the chemical energy of the food partaken of.

[9] Findlay, p. 51.

PHYSICAL TERMINOLOGY

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I

THE saying that "one ought not to investigate things from words, but words from things, for things are not made for the sake of words, but words for things" is credited by Diogenes Laertius to Myron. The fertility of this view is exemplified in the success of modern science. Words must be regarded as a means and not as an end. But this does not signify that, in the study of things, words should receive no attention. Myron implied that they should be investigated. In the natural sciences, words are not, of course, fundamental in the sense that instruments, processes and laws are fundamental. Yet, aside from mathematical symbols, they are the only means we have for giving unique designations to the things that are more important. These unique designations constitute the terminology of science.

Terminology must exist but it apparently has little to do with the nature of things. Consequently its problems usually fail to attract the scientist. The specialist can afford to be indifferent to words simply because to be a specialist is, in a sense, to have transcended such matters. Faulty terminology may become very troublesome in fields like spectroscopy and organic chemistry, or in attempts to interpret the material of one's own field in terms of the material of another. But in most of the older parts of physical science, the trained man experiences little difficulty. He knows that *radiation* denotes one form of energy, and *heat* another, so that *heat radiation* can not very well denote both. Without discomfort he employs such meaningless or ambiguous terms as *dark heat, gram molecule, vapor tension, latent heat, chemical ray, electric capacity, positive ray, electric force, electromotive force* and *permanent gas.* He realizes that many of these terms should be regarded as obsolete, even though the text-book writers do continue to use them. He knows that most of them have histories that clearly account for their existence. No matter how faulty a term may be, it is to him simply a symbol for a very definite concept and is without the flexibility of connotation that is characteristic of words in general.

This is all very well for the specialist. Yet if physical terminology is unnecessarily faulty and complicated, and there are reasons to believe that it is, then the scientist should give some attention to the mattter, if only to the end of its quicker disposal. One way to avoid boresome dialectic discussions is to have nothing to discuss.

Then, too, the general reader and the student not specializing in science need some consideration. Although they may not be important factors in scientific progress, nevertheless it is generally held that some knowledge of natural science is good for them and in some instances this knowledge is required. Hence some one is under obligation to render the elements of science intelligible. Not superficial but intelligible; to confuse the two is to confound vagueness of expression with profundity of thought.

II

The contention that a revision of existing terminology would materially simplify physics and chemistry for the beginner is borne out by the various vocabulary studies made by the educationalists. These studies seem to lead to the conclusions that the technical vocabularies of the elementary text-books are too

large and that there are too many new terms that are inadequately discussed. What naturally is not revealed by such studies is that there exist many terms that are inherently faulty or that need discussion for purely scientific reasons. This latter contention gains weight when one attempts to analyze terms in the light of their possible faults.

The remainder of this section is devoted to a brief discussion of some of the results of such an analysis. To facilitate discussion the various faulty and troublesome terms are divided into three classes: terms that should be discarded; terms requiring careful definition or special comment, and terms having more than one meaning.

There are many terms that should be discarded as working terms because they have synonyms that are less ambiguous or more meaningful. Among these are *sensible heat, theoretical mechanical advantage, uniform motion, mechanical equivalent of heat* and *latent heat*. Still other terms, such as *positive electron, quantity of magnetism* and *therm,* are not in themselves objectionable but should be discarded because there already exist more widely used terms having identical meanings. When one of these terms, such as *latent heat,* has unusual historical interest, there can not be any objection to its retention in the text-books, but it should be regarded as obsolete and labeled as such.

Many terms in common use represent concepts that are not important enough in the physical sciences to deserve special names. Some of these terms have been borrowed from the industrial arts, where indeed they may be useful. Some found their way into the text-books at a time, now remote, when apparently there was a want of subject-matter suitable for the elementary courses. Others originated in the anomalies and paradoxes of science, which, as Faraday has said, "only remain anomalies to us while we continue in error." Still other terms that may be regarded as superfluous, at least so far as the general student is concerned, are those which represent the reciprocals of quantities already having acceptable names. Examples of these various types of unimportant terms are: *anion, centrifugal force, diathermanous, conductance, magnetic length, consequent pole, penumbra, simple vibration, specific volume, concurrent forces, water equivalent of a calorimeter* and *anomalous dispersion.*

Needless contractions, such as *gravity, photo-current* and *radio-element,* form still another group of superfluous terms. Such contractions are often used interchangeably with their parent terms but with only the latter defined. Yet to the beginner, a contraction is a new term, for he has been taught that two scientific terms which differ only slightly in form, for example *resistance* and *resistivity,* usually represent unlike though probably related concepts.

To label this or that term as unimportant or superfluous is, of course, to invite an argument. The specialist is likely to regard most of the terms of his field as important, and rightly, since for his purposes so many of them are useful. For the general student, however, there are literally thousands of terms which might as well never be known. To select the most important terms might be a difficult task, but this should not prevent the attempt.

Particular attention should be given to terms which are undesirable but which are apparently too firmly established to be discarded readily. There are not many of them, but the few that do exist are often very troublesome. Usually they are very old or else have a popular origin and usage. Some of them originated in misconceptions of a fundamental character: *electromotive force,* which has the dimensions of energy divided by charge, originated at a time when force and energy were badly confused; *atomic weight*, which is neither a

weight nor a fundamental atomic property, originated when weight and mass were confused and when atoms were studied collectively, and not individually. *Four-cycle engine,* referring as it does to an engine having four strokes to a cycle, is an example of a misleading term having an established commercial usage.

Strange words also need special comment. To the beginner who is unacquainted with languages other than his own, particularly Latin and Greek, many terms seem as strange and meaningless as nonsense syllables. Several devices are available for overcoming this difficulty. It is a help to know the accepted pronunciation of a word, especially in the case of a foreign proper name. Expressions like *vernier, mass action, calory* and *fluorescence* are illuminated by their histories. *Vector, ion, colloid, hysteresis, moment* and *viscosity* gain content when their etymologies are known. Many other strange words, such as *achromatic, isotropic, amorphous* and *exothermic,* give no trouble to one who has learned a comparatively few prefixes and suffixes from which hundreds of terms are constructed. To be sure, many terms have outgrown their original meanings. *Inertia,* as Faraday pointed out, is now to be used metaphorically to express, not "idleness," but "habitude." *Atom* and many other terms have also lost their traditional meanings. To discard such terms is usually impracticable because of lack of suitable synonyms. To replace them by newly coined terms would lead to endless change and confusion, for even the acceptable terms of to-day may prove to be faulty when viewed in the light of tomorrow's discoveries. Fortunately many of them have become so completely divorced from their original meanings that trouble with them is unlikely. Thus, while the etymology of a term may throw much light on the history of a scientific concept, it is not a safe guide to modern usage. Resort to etymology simply helps to give a term content and renders it easier to recall.

Special attention should also be given in the text-books to pairs of terms like *dielectric constant* and *dielectric strength, gravity* and *gravitation,* and *thermoelectric* and *thermionic* because of similarities in form and meaning. Other terms in need of careful discrimination and comparison are *energy* and *force, energy* and *power, speed* and *velocity, density* and *specific gravity,* and *inertia* and *momentum.* One naturally would expect students to have difficulty in distinguishing these concepts, because many of them were badly confused in the early history of physical science. Unfortunately text-book writers carelessly encourage this confusion. Probably every physics text-book emphasizes the distinction in the definitions for pairs of terms like *speed* and *velocity,* and *energy* and *power,* but surprisingly few of them afterwards consistently employ these terms in their correct and separate senses.

A number of terms, of which *bar, power, Avogadro's number, molar* and *intensity* are examples, have two or more distinctly different technical definitions. Confusion often results, for the sense in which an author chooses to employ one of these terms is not always immediately evident, even to an experienced reader. In every case known to the writer, all but one of the definitions could be abandoned without the necessity of coining terms to represent the eliminated ideas. Since most of these terms are purely technical, such changes can easily be made by continuing the practice of including standardized definitions in widely used compilations like the International Critical Tables.

It is often necessary, particularly in elementary instruction, to simplify a concept and thus to employ a term in a modified sense. The occasion for this may rise because of mathematical difficulties or because of the inability of the

beginner to get an intuitional grasp of the original concept. Again, the original concept may be too general in nature for a given purpose, perhaps including insignificant or rarely observed phenomena. In this way, terms like *specific heat, electromotive force, entropy, instantaneous speed, force, temperature, calory* and *mass* come to have several definitions—an established, general definition and one or more simpler definitions. It hardly need be said that the simpler definition should represent, whenever possible, an actual special case of the established definition and that its limitations should be made as clear to the student as the nature of the subject permits.

Many words have both a popular and a scientific usage and the two usages may differ. This is the case with *work, pressure, degree of elasticity* and *action*. Many other words that the student is expected to know from his general reading or that he can find in ordinary dictionaries really are technical terms needing special explanation. One can not assume that the beginner has definite ideas about *tension, normal, rate, scientific, theory, uniform, experiment, critical, modulus* and *coefficient*. A knowledge of these familiar words usually comes about incidentally, and this informal learning too often consists, not of understanding words and situations, but of encountering them often enough to get over the unpleasantness of their strangeness. The text-books can not, of course, define every term, and if they did they would defeat one of their purposes, which is to stimulate collateral reading. Since ordinary dictionaries are not always to be depended upon for accurate definitions of scientific terms, it is unfortunate that we do not have inexpensive scientific dictionaries, specially prepared by men of science for use in elementary instruction.

The sciences borrow many words from every-day language and convert them to their own special purposes. On the other hand, many terms peculiar to science are put to non-technical uses. Both practices lead to confusion but are not always avoidable. To use a technical term in a metaphorical sense may not necessarily be a sign of bad taste on the part of the lay writer but it leads gradually to the misrepresentation of the original meaning of the term. What is worse, it tends to destroy the uniqueness of scientific language. Without a unique terminology, any field of knowledge is seriously handicapped, a fact of which the social scientist, for one, is well aware. Biologists might not have to give so much time to the correction of popular impressions if treatises on organic evolution could be clothed in the unfamiliar language of, say, mathematics. But for the blessings of a technical language the professional prohibitionists might busy themselves with relativity, or with quantum mechanics, perhaps to the end of denying us our wave-lengths, as our ancestors have been denied their tails.

Popularization of terminology leads also to a premature familiarity with strange terms which may breed contempt for their meanings. The jargon of a subject like radiotelephony, Freudian psychology or aeronautics is glibly employed by untrained persons with such apparent success that it indeed must seem to them unnecessary to acquire any fundamental knowledge of these fields. A confirmed radio addict seldom makes a graceful beginner in physics.

III

If this problem of terminology turns out to be largely a pedagogical one, it does not follow that it is a problem for the educationalist alone to solve. Physical science, fortunately, has reached the stage where the educationalist with a sense of scholarship will refuse to meddle with it without the assistance of the scientist. On the other hand, if a revision of terminology is a pedagogical

necessity, such a revision must not be attempted by the scientist alone. The demands of good scholarship extend in both directions. The specialist in science education is making progress in a genuine scientific study of subject-matter and technical vocabulary. His conclusions, when based on observation and experiment interpreted in the light of psychology, can not be ignored by the physical scientist, who above all others is in a position to appreciate the validity of such a method of obtaining knowledge. Of course it is also the pure scientist who is best able to foresee the enormous difficulty of obtaining reliable and fundamental experimental results in a field like education. Perhaps if a little more concern for these difficulties were evident in the work of the educationalist, his conclusions would be taken more seriously. However, if some of his results are untrustworthy and some of his conclusions far-fetched, they are hardly more so than were those of the early physical scientists. If his work in science education sometimes betrays a woeful ignorance of the nature and meaning of natural science, it can not be much worse than that of some physicists or chemists who attempt to teach without benefit of the principles of psychology as applied to education.

In all problems of science education, the scientist and the educationalist will eventually have to cooperate. In this matter of faulty terminology the initial responsibility rests with the scientist. He must put his house in order, for he is the only one who knows where things belong. The responsibility for correcting faulty terminology was recognized by men like Maxwell and Kelvin, both of whom were purists in matters of language. The few really outstanding text-books of physical science are usually characterized by a thoughtful selection of terminology and notation. But for the physicist and the chemist alone to determine what shall be the terminologies of their fields is not enough; technical vocabularies adjusted to the needs of various types of learners must be constructed, and here the scientist and the educationalist must work together.

Every experienced teacher knows that physics and chemistry present difficulties that are not disposed of by the assertion that there is no royal road to science. To attribute a part of these difficulties to vagueness of language is at first surprising, but it must be remembered that the terminology of established science was conceived during exploration, and the inevitable concomitant of exploring new fields of knowledge is a vagueness of ideas, with an accompanying vagueness of language. The hazy ideas of yesterday are reflected and, what is worse, preserved in the terminology of to-day. This does not provide an argument for a complete revision of terminology, but rather shows a complete revision to be impossible.

Any revision that is made will depend for its success upon the text-book authors and, still more, upon the teachers. The authors select the terms that appear in the elementary books, but the teachers select the books. The average teacher does not take kindly to a text-book that departs from the traditional type—a fact of which authors and publishers are well aware; hence innovations in language will be introduced into the text-books with caution. The chemists and the technologists are making progress in language reform through the medium of their committees on nomenclature. The technical journals can accomplish much, but they will always be hampered by the many readers who protest every attempt at language reform with the fervor of a fundamentalist. The most progress will be obtained, however, by convincing teachers and writers that a revision of terminology is practicable and that it really is an important step in making science more intelligible to the learner.

SCIENCE SERVICE RADIO TALKS

PRESENTED OVER THE COLUMBIA BROADCASTING SYSTEM

WEST INDIAN HURRICANES

By CHARLES L. MITCHELL

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MENTION of the word "hurricane" is quite likely to create an uneasy feeling in the minds of people living on or near our Gulf or South Atlantic coasts, or on any of the islands that comprise the West Indies and the Bahama Islands. And there is little wonder that such a feeling should now exist, especially in Porto Rico, the Bahamas or on the southeastern Florida coast, where at least one of these destructive storms has been experienced within the last two years. It has been our experience that after a hurricane has affected a certain area the inhabitants of that same area will be quite "jumpy" for two or three years, at least, after such a visitation, and that any intimation of the existence of a hurricane, no matter how far distant, or even the rumor of the existence of such a storm, will bring a flood of inquiries for information to the Weather Bureau.

Before going further, it may be well to say something of the life history of hurricanes. It should be of some interest to know that the typhoons of the Far East, the cyclones of the Bay of Bengal, the hurricanes of Australia and the islands to the north and east thereof, and the West Indian hurricanes are all practically identical in manner of development, intensity and general direction of movement, from east to west. However, because of the deflective force of the earth's rotation, which is to the right in the northern hemisphere and to the left in the southern hemisphere, the winds circulate around the center of the storm clockwise, *i.e.*, from left to right, in the southern hemisphere, and counter-clockwise, *i.e.*, from right to left, in the northern hemisphere. Furthermore, these revolving storms of the northern hemisphere recurve toward the north and northeast and those of the southern hemisphere toward the south and southeast after moving a number of days toward the west.

All you listeners-in have doubtless experienced a state of mind known as the "doldrums," when there was a sort of sense of depression with variable decisions that lacked force and permanence. There is likewise an area, or belt, called the doldrums, over the Atlantic Ocean north of the equator, between South America and Africa, that moves northward and southward with the sun, and in this belt there is a slight depression of the barometer, that is, the atmospheric pressure as measured by the height of mercury in the barometer is lower than over the ocean, either to the north or to the south of this area, the winds are light and variable, as a rule, and local thunderstorms of the usual afternoon convectional type are rather frequent. During the seasons of the year that this belt of doldrums is quite near the equator nothing happens other than the conditions just described, largely because of the fact that the deflective force of the earth's rotation is necessary in the process of initiating a cyclonic storm, and that force is so near zero on and near the equator that no such storms can originate there. How-

ever, in late summer and early autumn, the eastern end of the Atlantic belt of doldrums is so far north that it is close to the Cape Verde Islands, which are a short distance west of Cape Verde at the western extremity of Africa. Being between ten and fifteen degrees away from the equator here, the deflective force of the earth's rotation is quite sufficient to initiate a cyclonic circulation, granting that other conditions are favorable, while at the other end of this belt of doldrums on the coast of British Guiana, South America, which is only six or seven degrees away from the equator, the deflective force is too small, so that such storms do not develop there. Other conditions being equal, the farther removed from the equator a region is, the more likely it is that a cyclonic storm will develop there. It is generally agreed by meteorologists that high temperature and high humidity are favorable to, if not essential in, the development and maintenance of a tropical cyclone. Both these requirements are fully met in the doldrums between the system of northeast trade winds of the northern hemisphere and the southeast trade winds of the southern hemisphere. When the belt of doldrums shifts sufficiently far to the north, which is in the period roughly from the middle of July to the middle of September, the southeast trade winds change their direction, on account of the deflective force of the earth's rotation, and become southwest winds when more than about five degrees north of the equator.

Between these steady winds blowing from opposite directions is the doldrum area of light variable winds, high temperature and high humidity—all favorable for the development of local thunderstorms and squalls. At times these conditions increase in frequency and intensity for a few days, and then by some so-called "trigger" action, which is not thoroughly understood but which requires winds from opposite directions over the ocean areas to the north and to the south of the unsettled region, a cyclonic circulation is somehow set up around a center in the belt of doldrums. After the wind circulation is once started, there is a plentiful supply of energy from the latent heat set free in the process of condensation and precipitation of moisture in connection with the heavy rainfall that always accompanies tropical cyclones, so that the cyclonic circulation is not only maintained, but greatly increased, both in lateral and vertical extent.

Over the entire tropical zone the movement of the air from a comparatively short distance above the surface up to two or three miles is steadily from east to west nearly all the time. Therefore, as soon as the cyclonic storm has developed upward into this steadily moving mass of air toward the west, the cyclone is carried along with about the same velocity and direction as the great air mass above, much the same as a whirlpool in a stream is not only whirling around a center quite rapidly, but is carried down the stream with the main body of water. In the case of the tropical cyclone it is carried along toward the West Indies in a direction usually slightly north of west and at the rate of movement of the main air mass above, which varies as a rule from eight to eighteen miles an hour and averages about twelve to fourteen. This progressive forward motion of the entire cyclonic storm, or hurricane as it may now be called, must not be confused with the rate of movement of the air that is moving in toward and around the center, or vortex, of the storm. It is this tremendous velocity which in all hurricanes proper reaches at least sixty to eighty miles an hour near the center, and in the great hurricanes such as those of September, 1926 and 1928, reached 125 or more miles per hour. In the great hurricane of 1928 that devastated Porto Rico, the wind in the interior of

the island south of San Juan reached an estimated velocity of about 200 miles per hour, which is the greatest experienced in any hurricane of record. This is the nearest approach to the velocity of the wind attained in tornadoes of which we have knowledge. It is probable that in some tornadoes, judging from the effects, the wind attains a velocity of 300 to 400 miles an hour over an exceedingly small area. Hence the tornado is the most violent of all storms, but of exceedingly small extent, and the hurricane is next in violence, but covers a vastly greater area and, therefore, continues for several hours instead of a fraction of a minute as in the case of the tornado.

Now as to the method of receiving and disseminating information relative to tropical cyclones. The Weather Bureau maintains a network of observing stations where twice-daily observations are taken and sent to Washington, not only on the mainland of the United States, but also in the chain of islands that extends from Haiti around the eastern end of the Caribbean Sea to Trinidad, which is near the mainland of South America, as well as in the Panama Canal Zone and along the Caribbean coast of Central America. In addition, reports are received just as often from Jamaica and the Bahamas and from several stations in Cuba. Before wireless communication with vessels at sea was established, the bureau was able to detect and follow the paths of tropical cyclones when they approached and remained near any of these reporting stations on land, but it was much handicapped when they passed either north or south of the main chain of islands, with their centers far out to sea.

In recent years, however, the vessel-reporting service of the Weather Bureau has expanded greatly until now scores of wireless reports are received twice daily from vessels in the Gulf of Mexico, the Caribbean Sea and the western North Atlantic Ocean. Each report gives, in code, the location of the vessel (latitude and longitude), the reading of the barometer, the temperature, the direction from which the wind is blowing, the state of the weather and the velocity of the wind. All these data are plotted on the principal chart on which the regular weather forecasts of the bureau are based.

A brief account of the work of the Weather Bureau in connection with the great hurricane of 1928 will indicate the great value of the weather reports radioed from ships, and also the value of warnings issued by the bureau.

As stated before, the tropical cyclones that originate near the Cape Verde Islands are carried along in the general drift of the atmosphere westward toward the West Indies. Therefore, when two vessels nearly 600 miles east of Bridgetown, Barbadoes, the farthest east of the island observing stations at the eastern end of the Caribbean Sea, radioed their morning weather reports on September 10, 1928, and the data contained therein were plotted on the forecasting chart, it was instantly noted by the forecaster at Washington that the usual undisturbed conditions over that region of the Atlantic Ocean, where steady northeast trade winds and nearly stationary atmospheric pressure predominate, had been replaced by increased wind strength and falling barometer. This meant to the forecaster that a tropical cyclone was approaching these vessels from the east or southeast, and special reports later in the day from one of these vessels enabled the forecaster to locate quite definitely the center of the storm. Incidentally, this is the farthest east that the bureau has ever been able to detect the approach of a tropical cyclone. As a rule, there are few or no vessels in that particular ocean area, and furthermore, such vessels as do traverse that region are not always able to communicate with San

Juan, Porto Rico, by radio, because of too much static. Immediately after receipt of the vessel report just referred to, an advisory warning was prepared, giving the location of the center and direction of movement of this storm, and this warning was telegraphed to all the Weather Bureau stations on the Gulf Coast and to the Atlantic Coast stations as far north as Boston, so that vessels clearing from our ports could take proper precautions, if necessary, such as delaying their departure or changing their course. The warning was also cabled to Cuba, Haiti, Bermuda and the Bahamas, and was wirelessed by the naval radio stations to all ships at sea. While the storm center was still a few hundred miles east of the Lesser Antilles (which is that chain of islands that extends from Porto Rico around the eastern end of the Caribbean Sea almost to the South American coast), the warning sent out from Washington stated that the storm would pass over those islands the following day to the north of Martinique, and the center did actually pass over the French possession of Guadaloupe, about seventy miles north of Martinique.

The same procedure was carried out twice daily until this, one of the most severe and extensive West Indian hurricanes of record, reached Virginia as a disturbance of only moderate intensity on the evening of September 19. In each warning sent out for several days before its arrival on the Florida coast, the severity and the dangerous character of the hurricane were stressed, and the location of its center and its approximate direction of movement for the ensuing twenty-four hours at least, as well as the places it would likely pass over or near and the probable time of arrival, were given.

The effectiveness of the warnings in clearing the shipping lanes is well shown by the fact that not a single vessel report was received from near the center of the hurricane from the time the first warning was issued until the storm approached the Florida coast, when one vessel, for reasons best known to its master, steamed down along the southeastern Florida coast with the knowledge that the hurricane was close at hand, and it encountered winds of force 12, which, on the Beaufort Scale, means winds of seventy-five or more miles per hour.

At least thirty-six to forty-eight hours ahead of its arrival on the Florida coast, the Red Cross officials were advised of the danger to southeastern Florida, and the suggestion was made that a force of their workers be concentrated at Jacksonville and that the local chapters in the threatened area be advised to be prepared for emergency work. Evidently such action was taken, inasmuch as Judge John Barton Payne, in an appeal over the radio for public support of the Red Cross, stated that because of the warnings of the Weather Bureau the preparatory steps advised were actually taken so that the Red Cross was ready to function immediately when their assistance was sorely needed.

When there is great loss of life in a hurricane it is invariably due to drowning in low-lying sections where the great force of the wind causes the water to pile up over the low, but usually dry, land. Hence in the 1928 hurricane only twenty-six deaths were reported in the West Palm Beach area, while around the southern end of Lake Okeechobee, where the water attained a height of ten to fifteen feet on the shallow rim of the lake, there were approximately 1,700 deaths. The velocity of the wind was practically the same over both areas—more than 100 miles per hour. The great need of aid rendered by the Red Cross is shown by the fact that 10,172 families applied for aid during the month following the hurricane, about two thirds of this number being in Palm Beach County, which includes the Okeechobee area.

While eighty-four tropical cyclones of

hurricane intensity have reached the coast of the United States between Cape Hatteras and the mouth of the Rio Grande during the last fifty years, only sixteen of them can be classed as "great" hurricanes both as to intensity and diameter, and of these sixteen only two, both in southern Florida, have occurred within the last ten years.

A study of damage resulting from hurricanes shows that, aside from damage from high tides in low coastal sections and along large and shallow lakes, damage by hurricane winds to buildings constructed along or near the Gulf and South Atlantic coasts can be minimized if the walls and framework of buildings are sufficiently strong to withstand the wind pressure when the wind attains a velocity of from 100 to 125 miles an hour. It has been the experience of all Weather Bureau officials who have investigated the amounts and kinds of damage from hurricanes that even well-constructed frame buildings do not, as a rule, suffer more than relatively minor damage. Few well-constructed buildings collapse and either kill or endanger the lives of occupants, except possibly in the greatest of hurricanes. Inasmuch as the estimated property loss from hurricanes on the Gulf coast, including Florida, during the last fifteen years amounts to more than $150,000,000, and since a considerable part of this loss was due to wind damage alone, the desirability of sturdy building construction in that area is quite evident.

PSYCHOLOGY AND HIGHWAY SAFETY

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THE science of psychology, in other words the science of human behavior, is being drawn upon to help meet a national emergency, the emergency created by the rising tide of automobile accidents.

You do not need to be reminded how serious the situation is. In 1929 the fatalities increased 10 per cent. Every morning paper brings distressing evidence of the need for better ways of preventing accidents. Based on the latest figures of the National Safety Council, I estimate that in this country about eighty-five people are being killed every day in street and highway accidents, and more than twenty times that number hurt.[1]

The life insurance companies tell me that the automobile disease, as it may be called, now ranks along with tuberculosis among the ten major causes of death. For children five to fifteen years of age it heads the list. More of these boys and girls were killed last year by automobiles than died of diphtheria, scarlet fever or typhoid. The very little children not yet in school are specially liable to injury, also people over fifty years of age. But none of us, old or young, whether we drive, ride or walk, are wholly free from this danger. Probably among all of you who are listening there is scarcely one who is not now thinking of some relative or friend who has suffered in an automobile crash.

Until due account is taken of both the physical and the mental circumstances related to accidents, it is not possible to make a comprehensive workable plan for accident reduction.

The external physical conditions that lead to accidents have as a matter of fact

[1] The reported deaths from motor vehicle accidents this year to September 1 indicate a 6 per cent. increase over 1929. At this rate, the 1930 fatalities will be in excess of 33,000.

received more intensive study by safety engineers than the human or personal factors. Traffic engineers have given a great deal of thought to problems of routing, to devising better systems of traffic control. Civil engineers have been improving the design of highways in the interest of safety, and constructing road surfaces on which skidding is less liable to occur. Mechanical engineers have greatly improved the design of the automobile so that brakes and steering-gear are more dependable and more easily controlled. Others have been inventing road signs and markings that can be more quickly and easily seen, by day and by night. The various mechanical and material aspects of the safety problem, then, have had the attention of some of the ablest engineering brains.

But what of the driver at the wheel? He too is a problem. As a matter of fact only a minor part of the accidents that happen are primarily due to failure of brakes, tires, steering-gear, headlights, slippery road surfaces or other physical conditions. Indeed, we estimated at the time of the second Hoover Conference on Street and Highway Safety in 1926 that between three quarters and nine tenths of all the accidents are traceable mainly to failure of the human factor. This is why industrial psychology has been called upon to make its contribution to highway safety.

Industrial psychologists have been studying the causes of these automobile accidents, especially mental causes. When a policeman sends in a report of a collision he sometimes puts it down as caused by inattention. One of the state motor vehicle bureaus has classified as due to inattention nearly one fifth of all the accidents reported. The psychologist asks, why was this person inattentive? Why was his mind wandering at the crucial moment? Was it a fair companion who distracted him? Was it because of an illuminated advertisement that caught his eye? Or was the source of absent-mindedness within himself—some hidden worry or anxiety? You know how hard it is to concentrate on what you are doing when your mind is preoccupied with financial difficulties or a love affair or trouble at home or an argument you have had with the boss. Under such mental conditions you are more apt to be surprised by a sudden emergency or upset by the excited remark of a back-seat driver. You suddenly turn right when you meant to turn left, and before you know it you have ditched the car. The more we learn about these mental hazards of driving, the better prepared we are to overcome them.

Many other psychological factors have to be reckoned with also. There are too many people who can pass an examination for competence in operating a car, but who later develop wrong habits of driving, or who get rash or careless or a bit intoxicated, or are in too much of a hurry or who want to show off. Then they have accidents. Perhaps they get overtired, or develop a nervous headache or some other illness which makes it harder to keep concentrated on the job of driving—with disastrous results.

My wise friend Bill Pfouts used to say, "The best safety device is located above the neck—about four inches above the neck." What has psychology done toward improving the operation of this most essential safety device?

The story would be long, if all were told. Distinguished psychologists in Europe and America have delved into the mysteries of human motive and habit, attention and distraction, visual acuity, reaction-time, susceptibility to fatigue, self-control and other aspects of human nature in search of obscure causes of proneness to accident and ways of removing them. Our colleagues in England have studied the relation of accidents to proficiency and to various differences of ability and personality. They early proved that accidents do not

just happen; they are not distributed according to the laws of chance. In studying records of accidents among factory employees, street-car motormen, automobilists and bus drivers we too have found that more than half the accidents occur to a relatively small proportion of the men. These are the accident-prone people, the repeaters. They have had the same training and supervision as the others. They see the same posters and take part in the same safety drives. Yet they continue to have accidents. So the problem of the industrial psychologist is clearly that of developing the most effective ways of studying these accident-prone persons and helping them to overcome their particular tendencies.

Accidents have been largely reduced where this psychological approach has been added to the more familiar forms of effective safety effort—on the street-railways and bus services of Boston, for example, where we have had opportunity during the past three years to cooperate with the management, study the problem in detail and observe the benefits to employees and public which have followed the use of the measures recommended. There, under my direction, continuing studies have been carried forward and practical aids developed and installed. Collision accidents have been reduced one half. The Anthony N. Brady Memorial Gold Medal was recently awarded to this company for the best record in accident reduction of any street-railway system in the country. Men and management are proud of their fine accomplishment, and good-will toward the road has been increased among the car riders and pedestrians of the large metropolitan district which it serves. The financial saving, through reduction in deaths, personal injuries and property damages, in 1929 exceeded $300,000. The application of industrial psychology to accident prevention has its economic as well as its humanitarian values.

One of the important points we have been investigating is the relation between slight mishaps and serious accidents. Wherever adequate records have been made available, we have found that those people who have a large number of minor accidents are on the average more apt to meet with a serious disaster some day. The problem is how best to discover these accident-prone men and help them to become skilful, safe operators before they meet with a bad accident. Nearly all these men are just as anxious to avoid accidents as any one. They do not know why they so often have "tough luck" as they call it. It is our duty to find out why they have such bad luck and then help them to develop correct habits and right mental attitudes so that they can more surely avoid accidents. This has been done with marked success. The resulting decrease in accidents has been brought about, I am proud to say, not by discharging the men with bad accident records and hiring others, but by helping these men to change their ways and become competent, careful drivers. What these men have done, others can do. I believe you will agree that a large majority of the automobile accidents happening to-day are really quite unnecessary.

I am often asked whether men or women make the better drivers. Women have fewer accidents than men, but this is not because they are better drivers on the average. It is because they do not do so much driving. When men and women have a chance to operate the same kind of vehicle over the same streets for the same number of hours a day, the women have about three times as many collisions as the men. This fact came to light in a study of men and women taxicab operators in Philadelphia, published in the *Personnel Journal* for February, 1929.

Women and girls have the advantage over men in at least one regard. Not

nearly so many of them are color-blind. They rarely have any trouble in telling red from green. But the latest researches show that about one man in twelve is born with this peculiarity of the retina. When a driver runs by a red light it is sometimes because his eyes are defective in this respect. If such a person goes to the garden to get some tomatoes, he is apt to come back with a few green ones in his basket along with the red ones. All tomatoes look alike to him. When he is driving an automobile he naturally tends to confuse red and green signals. Curiously enough, many such drivers are quite unaware that they have this handicap.

So psychologists have cooperated with safety engineers in standardizing the colors to be used in highway signals. They have found the particular hues of red and green that are least apt to be confused, even by drivers with this color defect. They have also undertaken to arrange these signals so that even the color-blind eye can readily tell them apart by their shape, position or number.

Color-blindness and other visual defects, however, are not among the major causes of highway accidents. Neither is slow reaction-time as serious a matter as is sometimes supposed. Variability of reaction-time is a better indicator of proneness to accident. A habitually narrow, focalized attention is thought to be a handicap, since a driver needs a certain dispersion of attention; he needs to know the total situation, to be aware of what is happening on both sides of him as well as directly in front. He also needs imagination enough to anticipate what the other driver is going to do next, or the little child playing beside the road. Some operators are handicapped by excessive perseveration, the tendency to keep right on doing whatever one has begun to do. Others are hard of hearing. One of my friends has to drive with only one arm. But whatever a person's natural handicaps may be, the amazing thing is his capacity to compensate for these defects. We have been astonished again and again at the ability of all sorts of people to acquire the knowledge and the skills necessary for operating an automobile safely. Even the very dull, with no more intelligence than a high-grade moron, can do it, if they are emotionally stable. The capacity of people to learn is very great, provided the training they receive is properly adapted to their individual personal needs.

But until a driver can demonstrate that he has acquired these essential abilities he ought not to be allowed on busy streets. This is why some states require examinations for driver's license.

The driver's examination ordinarily includes a practical road test, so that the examining officer has a chance to observe how skilfully or awkwardly you can handle a car in traffic. Some examinations include tests of hearing and eyesight. You are also examined either orally or in writing to see how well you know the laws of the road, the ordinary courtesies and customs of driving and the state and local regulations, including what to do about reporting any accident that may happen.

These examinations have proved to be of real value. No good driver need be afraid of taking such a practical test; and if a driver is not competent, then he is not wanted on the road, blocking traffic, making wrong turns or doing the foolish thing in an emergency. You know there was an alarming increase in the number of people killed by automobiles last year. The total exceeded 31,500. But the increase was mostly confined to those states which do not yet have a well-administered examination for driver's license. If you live in one of those states, your chances of being killed or hurt are unnecessarily high. Would it not be a good idea for you to write or talk to your representative in

the state legislature, and ask him how much longer you must wait before you too have the benefit of a good driver's license law?

The psychologists who have been studying the problem of preventing accidents are thoroughly in sympathy with the movement for drivers' examinations. Indeed, they have done a good deal to improve the methods of examination—to make them more practical, more thorough and at the same time more simple to administer. For example, twelve years ago they developed and standardized for the United States Army the practical tests for truck drivers and chauffeurs which have ever since served as model examinations. At the present time, psychologists and state motor vehicle administrators are cooperating to make such examination methods still more practical and useful.

Sifting out the most incompetent drivers by means of license examinations is, however, only one step toward accident reduction. Even more valuable is the special examination of the driver with a bad record who is brought before the authorities for a hearing to see whether his license should not be revoked. This examination aims to go to the root of the matter, to find out whether the man's unsafe driving is due mainly to his constitutional slowness or lack of muscular control; or to his ignorance, his lack of practice, his wrong attitude toward other drivers; or to his health, his emotional instability or some other complicating cause. Then a decision is reached as to whether he is probably capable of becoming a safe driver; if so, he can be started on the right road to that destination.

Policemen, judges of the traffic courts, motor vehicle administrators and public all share this responsibility for helping the dangerous automobilist to change his behavior for the better.

Industrial psychology has not yet solved all the problems of accident susceptibility, nor discovered all the effective means of curing drivers of their dangerous ways. Indeed, scarcely more than a good beginning has been made. I believe you will agree, however, that this psychological approach to the problem is essentially sound. You can put it to the test by observing your own habits of driving, your own thoughts and motives while at the wheel, your attitudes toward other drivers and toward pedestrians and your behavior when a sudden emergency arises. This is a fascinating game. Who knows but what it may help you sometime to avoid one of these all too common automobile fatalities!

HEREDITY AND ENVIRONMENT

By Dr. ALBERT F. BLAKESLEE

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This last summer a newspaper reporter asked me to predict the future of the Lindbergh baby from the standpoint of its inheritance. The reporter seemed to think a student of heredity ought to be able to tell what a child will amount to if he knows what its parents have accomplished. I declined, however, to be a fortune-teller and give a detailed horoscope of the infant. No doubt I was expected to say that the child will become a great flier like his father. If the child should spend many of his future hours in the air, as he doubtless will, would this be chiefly because he has inherited his father's

capacity to learn aviation or chiefly because he is brought up in aviation surroundings? In other words, would flying in his case be due to heredity or to environment? As a matter of fact it would probably be due to both. The capacity to learn to coordinate body and mind necessary to one who guides an airplane is undoubtedly inherited. The flyer Lindbergh inherited such capacity from his ancestors, although his ancestors never had an opportunity to show this capacity in actual flying. They lacked an aviation environment. On the other hand, whatever our heredity, probably most of us who are listening in will fly before we die, at least as passengers, and many of us hope to make flights with our own wings afterwards.

If I had made the prediction that Baby Lindbergh would become a Congressman I would have had some justification from both his heredity and his environment. One grandfather was a Congressman and the other grandfather seems likely soon to be a Senator. His environment is no less propitious than his heredity. He was born in a household which was conspicuous in the political world, and he is likely to be brought up in an atmosphere in which political ideals are familiar.

The future of Baby Lindbergh, and of every other baby, will depend upon the potentialities with which it is born and the development of these potentialities by means of the surroundings to which it is subjected. In other words, the future of the child is determined by the interaction of the two major factors controlling life—heredity and environment.

The biologist does not mean by heredity the so-called inheritance of money or of antique furniture. He means by heredity what the individual receives from his ancestors not as visible heirlooms but as capacities to develop and respond in definite ways under different surroundings. The surroundings or opportunities to which the individual responds form his environment.

Man is subject to the same biological laws as other animals. But man is not a convenient animal for experimentation. The laws of life in consequence have been discovered chiefly through experiments with other animals and with plants. You would probably all agree, from your own observations, that no two human beings are exactly alike. Probably the same is true of at least the higher plants and animals. I used to take my students to an apple-tree and ask them to find two leaves that were exactly alike, that is, two leaves which when placed one over the other would correspond in size, shape, teeth on the margins and veining. Each year the class would start with the idea that it would be easy to find two identical specimens of such a relatively simple structure as a leaf. They all finally would agree, however, that probably in no kind of tree could two leaves be found which were exactly alike. It might be pointed out that the peculiarities which enable one to distinguish the leaf of an apple from that of another kind of tree, such as a peach, for example, are due to differences in its parentage or in other words to its heredity. The differences between the leaves on the same tree are due to differences in environment during their development, such as differences in light, in position on the twig, in vigor of growth, etc.

During the last thirty years much has been learned about the cause of differences between living things. Environmental influences such as light, temperature and food, including the vitamins, have been found to affect profoundly the structure and reactions of plants and animals. A mechanism of inheritance has been discovered. It is now known that characteristics are not transmitted as such from parent to offspring. What is inherited are rather hereditary units which interact and

give the plant or animal the power to respond in a certain way to a given kind of environment.

If the environment is changed, the plant or animal may respond in a different way without changing its heredity. Thus if we dislike pink-flowered hydrangeas we can make their flowers blue by adding iron salts to the soil. But their offspring, whether they came from pink or from blue flowers, would be alike. In both cases they would inherit the same power to respond to the amount of available iron in the soil, and their color would depend upon how much iron they were able to absorb.

An example may be given from animals. The so-called Himalayan breed of rabbits is white except for its extremities which are black. It was discovered by experiment that if the temperature of the skin were lowered, the hairs that grew out would be black. This particular breed of rabbit inherits the capacity to develop white hairs if the temperature is high and black hairs if the temperature is low. Whether the animal had white or black hairs, however, would make no difference in the color of its offspring — no more than would dyeing the hair of the mother with whatever cosmetic humans use to make gray hair look young. It is not color of hair as such that is inherited in this breed of rabbit but rather the power to produce white or black hairs in response to a high or low temperature environment. Most breeds of domestic rabbits do not inherit the power to respond to temperature differences in their environment by a change of coat color. They are either white or pigmented at all temperatures.

It is often difficult to decide whether to attribute a difference between two forms primarily to heredity or to environment. I sowed two batches of seed from a single ear of corn. One batch I planted in hills far apart. The variety had inherited the power to grow tall under favorable conditions and the plants reached a height of ten or twelve feet. The other batch of seed I planted close together. They grew only three or four feet high. Shortness in this case might be attributed to environmental factors of crowding, since the heredity was the same. Another variety of corn, called the Tom Thumb variety, was planted at the same time in hills far apart and in the same kind of soil. It was a dwarf variety and grew only three or four feet high. In comparison with the variety of tall corn under similar environmental conditions, the shortness of the Tom Thumb variety might be attributed to heredity, since the environment was the same. Thus it will be seen that both heredity and environment may bring about similar effects. The shortness of growth in corn is an example.

Now what about the effects of heredity and environment upon the next generation? Seeds from the Tom Thumb dwarf variety gave dwarf plants the next season, as might have been expected from the heredity of this variety.

I planted also seeds from the corn plants which had been dwarfed by crowding, alongside of seeds from the tall corn which had been grown far apart. There was no difference in the height of the offspring that resulted. The dwarfing due to the environment had not been inherited.

Environment and heredity as causes are fundamentally different. Environment works upon the individual and its effects are transient. Heredity works upon the offspring and its effects are enduring, from generation to generation. Inherent characteristics only are transmitted. It has been generally assumed, however, that characters acquired as a response to a good or to a bad environment are handed on to the next generation—that a man's college education, for example, will affect the

mind of his newly born children. Increasing knowledge has failed to support this assumption. So-called acquired characters seemingly can not be handed on to one's descendants.

It follows, therefore, that no amount of exercise of mental or of physical powers of parents can directly affect their children. A man blinded at birth would have no opportunity to practice the painter's art, however great the artistic gifts with which he was born. Yet his children would inherit no less artistic power than if he had retained full sight and become famous by his artistic production. This is not to say that in both cases the chances would be equal of his children developing into recognized artists. On the contrary, any artistic education of the father would be handed down by example to the children and this environment would afford them a better opportunity of recognizing and developing any artistic talents they might have inherited.

We start life like a photographic plate which has been exposed. There is a potential image ready for development, which corresponds to the heredity. Chemical solutions in the hands of the photographer furnish an environment which reveals the lines already impressed upon the negative. Differences in this environment brought about by changes in the manner of developing the negative may alter the appearance of the finished picture. And yet the development can bring nothing new into the picture. Its outlines were foreordained at the moment the sensitized plate was exposed in the camera. After we are born, we can not change our heredity, though we can change our environment.

The facts that have been presented may appear familiar and the distinctions drawn trivial. But the distinctions lie at the base of all efforts for human betterment and are far from trivial in their significance.

The distinction between heredity and environment and their relative influence should be carefully estimated in any rational campaign for permanent social improvement. Our ideals and practice in social and religious justice and in charity and education are fundamentally dependent upon our estimate of the relative value of these two factors. If one is born with inherent criminalistic traits, for example, the environment may be in no way responsible, and can thus be neglected. Shall we, however, merely punish the individual or shall we attack the real cause of the crime—his heredity? On the other hand, if the criminal is made such by his environment, shall we confine our attention to the criminal and neglect the environment which has made him a criminal?

In this brief talk I have tried to show that what every living being is and does is dependent upon the constantly interacting factors of heredity and environment. Every thought and act of our lives is influenced by these two factors.

The question is often asked if a particular type of personality is due to heredity or environment, as if it were due to one and not to the other. The question finds expression in the phrase nature *or* nurture. The phrase should read rather nature *and* nurture, or, in the words of the title of my talk—heredity *and* environment.

INVESTIGATING TETANUS (LOCKJAW)

By GEORGE E. COLEMAN

UNIVERSITY OF CALIFORNIA

THIS is an era not only of outstanding scientific achievement but also of educational activities sponsored and aided for the benefit of the people by scientists themselves. Particularly is this true of the medical sciences, and fortunately so, for in no other field is it possible for an interested and suffering public, avid for reliable information concerning health and disease, to be so led astray. Radio broadcasting by the American Medical Association, educational medical films, lectures by hospital staffs, life insurance pamphlets and authoritative books and articles in magazines and newspapers are all rapidly opening for the masses the gates to a field hitherto closed and more or less wilfully hedged with secretiveness. The public is at last and truly becoming scientifically minded and therefore able to realize more and more some of the difficulties inherent in the solution of the most baffling medical problems. The details of the investigations of some of those successfully solved would, if described in the vein of Fabre's works on insects, thrill the reader like a best seller among detective stories, for they too deal with life and mystery.

While cancer continues to take its enormous annual toll of human lives there is another disease—tetanus, popularly called lockjaw—which is fortunately far less prevalent but equally or even more deadly. This disease possesses many fascinating problems for the medical investigator. These hinge largely upon the many peculiar properties of the germ of tetanus (Clostridium tetani).

BACTERIOLOGY

Let us visualize the microscopic picture of this bacillus when it is grown in pure culture and has reached the stage of sporulation. All one sees is innumerable short, thin rods, many of them with a perfectly spherical ring or ball (spore) at one end. These are called drum-stick forms. There are also seen many free spores which have lost their bacillary attachment. This organism grows and produces its fatal toxin or poison only in the absence of free oxygen. It is therefore called an anaerobe. The bacillus also forms a spore—a resting stage or form of resistance which enables it to perpetuate the species under adverse conditions, such as drying or lack of proper food, which would permit it to continue to propagate by division of its cells. Tetanus is not a contagious disease but develops only after deep punctured or contused wounds are received in which dirt or something else contaminated with tetanus spores may have entered.

There are several other species of spore-bearing anaerobes which cause fatal wound infections, particularly that of gas-gangrene, but none forming spores more resistant to heat and antiseptics. Nor do we know of any which produces a more potent toxin or one which acts on the nervous system in such an insidious or peculiar way.

THE POISON

In passing I should mention the anaerobe Clostridium botulinum which produces a powerful poison in canned and preserved foods and which has been the cause of many fatal outbreaks of botulism. This organism perhaps shares with the tetanus bacillus the doubtful honor of producing one of the most deadly poisons of any living thing. We know little quantitatively of the toxic

secretions of insects, but judging from the effects of the minute quantities injected when they sting, it is possible that some of them are as potent as that of the tetanus bacillus. To give an idea of the amount of poison produced by a very toxic strain of the tetanus bacillus when grown in a favorable liquid medium—if one were to mix one drop of the culture with ten quarts of water, twenty drops (approximately one cubic centimeter) of this mixture injected under the skin of a mouse would kill it within four days. This amount would be called the minimum lethal dose (M.L.D.) of this culture and contains about one ten-thousandth of the original drop. It would also be equal to one cubic centimeter of the culture diluted two hundred thousand times. We know the relative susceptibility to tetanus toxin of the various animal species and birds used in bacteriological research but practically nothing quantitatively regarding man. It has been estimated from clinical data that, excepting the horse, he is probably the most susceptible of all.

The resistance of the spores to dry heat and boiling varies according to the particular strain and other conditions. Certain strains will resist a boiling temperature for over an hour, while those of the botulinus organism will resist boiling for five hours. Both are also extremely resistant to antiseptics, and certain strains of tetanus spores may survive over one hour in dilute commercial lysol.

Another feature which adds to our difficulties in the study of Cl. tetani is its very special nutritional requirements. Most material to be examined (stools, earth, wound exudates) are teeming with other bacteria in vastly greater numbers than the tetanus organisms. These outgrow and overgrow the latter in culture, which makes isolation and proof that the material contains tetanus spores or bacilli very difficult. Then, too, the metabolic products produced in culture by these other organisms often destroy what small amount of toxin may be formed by the growth of the tetanus bacilli, if present, and so mouse inoculation is often of no avail in proving the presence of tetanus toxin.

So much (perhaps too much) for the bacteriology of tetanus. Before considering the natural and experimental disease it will be necessary to touch briefly upon the question of immunity.

Serology

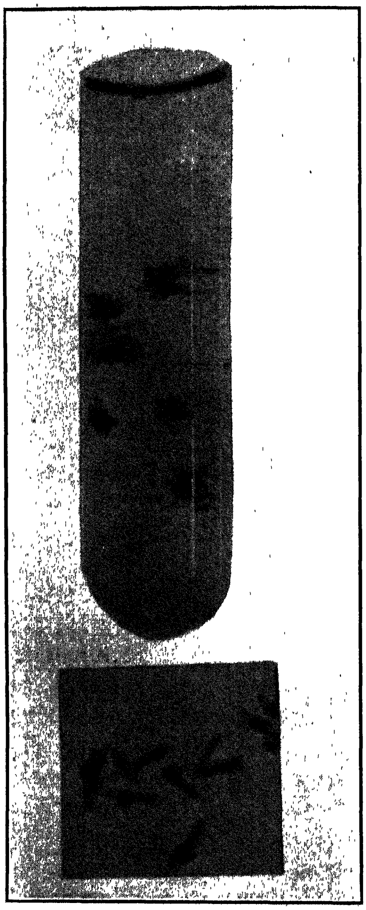
If an animal be injected two or more times with the bacilli, washed to free them from their toxin, within about three weeks its serum, separated from the clotted blood, will acquire a peculiar property. If a few drops of this serum, even diluted many thousand times, be added to a homogeneous saline suspension of the same strain of bacilli which was injected, in a short time the bacilli will all clump together. No amount of shaking will separate them. This is called agglutination, and is a very reliable and constantly used method for the diagnosis of certain diseases as well as for estimating the relationship which may exist between strains of the same bacterial species. Formerly it was supposed that all tetanus strains were alike. Thanks to an intensive study of this phenomenon begun during the war, we are now able to differentiate nine types of this species. Five were discovered in Europe, two in China and two at the University of California. All types have the same morphological and cultural characteristics as far as can be determined.

Immunity

Nearly every one now knows something about antiserums or antitoxins since the immunization of children against diphtheria has proved such a boon. Briefly, the serum of an animal will after a time acquire the property of neutralizing, either in the test-tube or in

the body, the toxin of certain species (tetanus, diphtheria, botulinus, scarlet fever) after the animal has been injected with several gradually increased doses of any one of these toxins. This reaction is specific only for the kind of toxin injected. This applies to snake venoms and other substances as well. For purposes of immunization of both man and animals, formerly tetanus toxin was partially neutralized with antitoxin before being injected, but a newer method is now practiced which avoids the use of antitoxic serum and includes a modification of the toxin by formalin. This chemical destroys the very toxic principle of the toxin but leaves intact its immunizing bodies. The use of this latter product with human beings avoids possible serum sickness. It is called anatoxin, while the other is called toxin-antitoxin. Antitoxic serums from horses immunized against tetanus are now concentrated and standardized so that one cubic centimeter (about twenty drops) of a potent serum is often obtained which will neutralize one to two million guinea-pig minimum lethal doses of toxin. This is the product which is now used to prevent and to attempt the cure of developed tetanus in the wounded.

By the injection of formalinized bacteria and spores into animals one can produce an antibacterial or an antispore serum which has distinct bactericidal or sporocidal properties—at least in the test-tube. It is the hope of research to prevent the growth of tetanus spores and bacilli in the body by this means. As yet no clear-cut results have been obtained with tetanus, but recently English workers have obtained some very promising leads with other wound-infecting anaerobes. The question as to whether these sera obtained with one type of tetanus bacillus will be effective *in vivo* against all other types is still undetermined. This is perhaps the most important problem before us to-day.



GERMS OF TETANUS

ABOVE: COLONIES OF CL. TETANI GROWING IN AGAR. BELOW: TETANUS SPORES FROM A CULTURE MAGNIFIED 1,300 TIMES.

TETANUS CARRIERS

About 25 per cent. of the normal population of the San Francisco Bay region have tetanus spores in their intestinal tract. It has been claimed by one worker that "carriers," to a great extent, are immune to tetanus, but neither the writer nor any one else as far as the literature has revealed has ever found a trace of antitoxin in normal human sera whether of carriers or non-carriers. Some normal human sera, however, very slightly diluted will agglutinate certain types of tetanus bacilli—some, in fact, several types in the same individual. It has been pretty well dem-

onstrated that immunity to tetanus is a humoral property and is not something inherent in the cells of the body. That is why we estimate the degree of immunity by the antitoxin content of the serum. It is possible that the carrier state is transient in any given individual. One can feed millions of tetanus spores to guinea-pigs several times in one week, and often two or three weeks later none can be demonstrated in their stools. These studies are important because in our attempts to produce the most effective preventive or curative sera we must follow the agglutination, sporocidal, bactericidal and antitoxin reactions of the serum as the immunization proceeds. This is in order to elucidate the question of the possible effect of the carrier state in immunity to tetanus.

A GUINEA PIG WITH TETANUS
AN INDIVIDUAL INFECTED WITH TETANUS SPORES IN LEFT HIND LEG. NOTE THE TWISTED SPINE.

THE DISEASE

Tetanus spores are usually more numerous in soil that has been fertilized over long periods with manure. That is why during the World War such a large number of the wounded in France developed tetanus. The writer was at the Pasteur Institute at the beginning of the war, and as the Germans neared Paris the first thought of the French was to save their precious immunized horses and to remove them from the city. The serum, however, was soon exhausted and tetanus took a heavy toll. Later on when hundreds of horses became immunized in France and England every severely wounded soldier received one or several injections of antiserum to neutralize any tetanus toxin which later might be developed in the wound. Thousands of men were thus saved from this dread disease. Others also, though receiving preventive doses of serum, developed the disease and some died, although serum treatment in enormous doses was continued. Under just what conditions does our preventive serum protect and all too often even in enormous quantities fail to cure the developed disease? That is what we are trying to find out. The layman has no idea of the years of study by numerous investigators all over the world or of the thousands of mice and guinea-pigs sacrificed to try to solve this and other riddles of medical science.

The tetanus bacilli developed from spores for the most part remain in the wound and produce their toxin there. Their development is aided by the oxygen-consuming ability of other bacterial contaminants (called aerobes), by the tissue debilitating substances produced by them and by other anaerobes and by a host of other factors only partially elucidated. The question of whether tetanus spores will develop in a wound is apparently determined not so much by the ability of the white blood

corpuscles to destroy them as by the degree of oxygen tension which may exist there. Where pus and extensively devitalized tissue is present this may possibly fall to zero and the spores then develop.

As the period of incubation of tetanus in the wounded may vary from three or four days to six months or more, in fact long after the wound has completely healed, the mechanism of tetanus infection becomes one of the greatest complexity. The toxin produced when development begins gradually increases as the bacilli multiply. This creeps up the motor nerve endings almost as a root-fiber sucks up moisture, and beginning in the affected part slowly paralyzes the entire motor nervous system. When once this combination of nerve substance and toxin takes place, no known medical procedure can separate them. Nor can the continued absorption of the toxin be prevented except (1) by the neutralization of uncombined toxin which, when rapidly produced, also enters the blood stream and may be absorbed by nerve endings all over the body, and (2) by the prevention of the further development of bacilli in the wound. In developed tetanus these continued injections of large quantities of antitoxin undoubtedly take care of much of the free toxin remaining unabsorbed by the nerves, but unless the development of the bacilli can be controlled there is a limit to the endurance of the sufferer, and he dies, especially if treatment is not begun early and continued vigorously.

Experimentally our first endeavor is to reproduce the natural infection in animals with counted spores. Even when injected after severely devitalizing the muscle with other bacteria or chemicals, until recently several hundred million spores were required to infect guinea-pigs. A method has now been perfected at the University of California which enables us to produce tetanus with only ten to fifty spores. With this number in all probability natural infection is more nearly simulated, toxin production reduced and more accurate results obtained in the study of preventive or curative serums.

The particular questions involved in prevention are those concerning the prophylactic serum. The toxin of all types of tetanus bacilli is neutralized by the serum produced by immunizing animals with the toxin of any one of the nine given types thus far discovered. But this serum, as now prepared, probably plays a negligible part in actually preventing the germination of tetanus spores in a wound. Other factors determine this, and the antiserum merely neutralizes the toxin if it is not too rapidly produced. In the meantime the natural defensive mechanism of the body may stop the bacilli from growing. When this does not occur may it not be possible more surely to prevent or to cure developed tetanus if our present antitoxic serum can be made to include spore or bacterial growth-inhibiting substances? This is another one of our major problems. Some eminent English investigators feel that the serologists have done all they can and that the physiologists will now have to continue the work. Many physiological investigations with drugs are in progress with a view to the reinforcement of the natural defenses of the body in its resistance to the infection as well as to the effect of the absorbed toxin, but the complete solution is not yet in sight.

It is thus that scientists work and struggle to expose the hidden secrets of nature and to control her processes. Meanwhile humanity waits, but with justifiable hope. Its part is to encourage science by its interest and appreciation and to furnish the necessary material aid that greater numbers of competent scientists may be highly trained and thus hasten the solution of our complicated problems.

THE PROGRESS OF SCIENCE

THE FIFTH INTERNATIONAL BOTANICAL CONGRESS

THE Fifth International Botanical Congress at Cambridge, England, under the presidency of Professor A. C. Steward, of Cambridge University, August 16 to 23, 1930, was initiated by a formal reception to delegates and members of their families at the Imperial Institute in London on Friday evening, August 13. The following morning a special train took the delegates to Cambridge, where the congress officially convened on Monday morning, August 16.

The presidents of the sections were as follows: Bacteriology, Professor R. E. Buchanan, Iowa State College; Phytogeography and Ecology, Professor H. C. Cowles, University of Chicago; Genetics and Cytology, Professor O. Rosenberg, Botaniska Institutet, Stockholm; Morphology and Anatomy, Professor J. C. Schoute, Gröningen; Mycology and Plant Pathology, Professor L. R. Jones, University of Wisconsin; Plant Physiology, Dr. F. F. Blackman, Cambridge University; Paleobotany, Dr. D. H. Scott, Basingstoke; Taxonomy and Nomenclature, Professor L. Diels, Berlin.

The scope of this paper does not permit a detailed consideration of the numerous and important papers that were presented before the various sections of the congress. Abstracts of these communications were published in advance of the congress, forming a book of 327 pages, copies of which were supplied to all delegates. Provision was made for the ultimate publication of the full proceedings, and the papers presented are now in the hands of the editorial committee.

The executive committee of British botanists, charged with making detailed arrangements for the congress, is to be congratulated on the excellence of their program and the manner in which the numerous items were handled. The very efficiency of this committee added greatly to the pleasure and convenience of the numerous overseas delegates.

All meetings were held in the lecture rooms and laboratories of Cambridge University, and the majority of the delegates were housed in the various colleges of the university. Because of the most attractive surroundings, the ample space for conferences, exhibits, etc., and the close proximity of the various buildings, the numerous delegates who were fortunately able to attend the congress will long remember the pleasant associations there formed, and all keenly appreciated the whole-hearted hospitality and the numerous courtesies extended to them during their stay in Cambridge and in England.

Various important excursions were arranged for visiting delegates before, during and after the congress. These included a pilgrimage to Halesworth Church to attend the dedication ceremonies of a memorial tablet to Sir Joseph Dalton Hooker, born at Halesworth, and Sir William Joseph Hooker; to the English beech woods in West Sussex, Cheltern Hills, Cotswold Hills and the Wye Valley; to Blakeney Point and Scolt Head to inspect their maritime vegetation; to Wicken Fen to examine the swamp vegetation; special field excursions for plant pathologists; excursions to the Rothamsted Experimental Station, Harpenden; the John Innes Horticultural Institution, Weston; Messrs. Sutton and Sons Seed Establishment and Trial Grounds, Read-

EXECUTIVE COMMITTEE AND OFFICERS OF THE BOTANICAL CONGRESS

LEFT TO RIGHT, FRONT ROW: H. HARMS, G. W. E. LODER, B. NĚMEC, F. A. F. C. WENT, C. SCHRÖTER, E. D. MERRILL, L. DIELS, A. C. SEWARD, G. R. WIELAND, H. C. COWLES, J. C. SCHOUTE, K. DOMIN, R. MAIRE, A. B. RENDLE, J. BRIQUET, DAVID PRAIN. SECOND ROW: T. F. CHIPP, O. STAPF, A. RENIER, W. GOTHAN, W. J. JONGMANS, NELLIE CARTER, E. RÜBEL, T. A. SPRAGUE, R. E. FRIES, O. ROSENBERG, N. E. SVEDELIUS, HELEN GWYNNE-VAUGHAN, A. PASCHER, R. R. GATES, S. ORLA-JENSEN, R. E. BUCHANAN, E. R. SAUNDERS. THIRD ROW: F. T. BROOKS, M. KORCZEWSKI, W. SZAFER, F. F. MATURANA, F. F. BLACKMANN, W. L. BALLS, P. BERTRAND, B. SAHNI, T. G. HALLE, A. W. HILL, E. G. D. MURRAY, W. N. EDWARDS, O. WINGE, J. RAMSBOTTOM. BACK ROW: H. O. JUEL, F. E. FRITSCH, A. D. COTTON, R. KRÄUSEL, W. STILES, G. E. BRIGGS, A. G. TANSLEY, V. H. BLACKMAN, R. PAMPANINI, H. H. THOMAS, H. GODWIN, H. GLÜCK, H. H. DIXON, F. E. LLOYD.

ing and Slough; Messrs. James Carter and Company Seed Establishment and Trial Grounds, Raynes Park. Through the courtesy of the president and council of the Royal Horticultural Society, the garden of this society at Wisley was open to delegates; the same courteous arrangement was made by the trustees of the Chelsea Physic Garden. A special exhibit of material of historic interest was arranged in the department of botany, British Museum (Natural History). At Kew a personally conducted tour through the Royal Botanic Gardens was provided, with an al fresco luncheon for visiting delegates. A special exhibition of Linneana was arranged at the rooms of the Linnean Society, Burlington House, London.

The Fourth International Botanical Congress held at Cornell University, Ithaca, New York, in 1925, had charged the 1930 congress with the difficult and complicated task of revising the International Code of Botanical Nomenclature. This was unquestionably the most important single project that came before the congress. The international committee, under the leadership of Dr. John Briquet, of Geneva, had carefully assembled and collated the data that were to be presented for discussion, these data being supplemented by a 200-page document consisting of proposals by British botanists. The "Recueil synoptique" and "Avis préalable," prepared by Dr. Briquet and his colleagues, contained all the suggested modifications of the International Code that had been submitted by botanists from all countries; in parallel columns were given the original text of the 1905 and 1910 rules, together with the suggested changes and with the recommendation of the international committee.

With these carefully and critically prepared documents, the Section on Nomenclature, under the chairmanship of Dr. E. D. Merrill, proceeded to a consideration of details. Practically all the recommendations of the central committee were approved, there being at times a very lively discussion from the floor. As discussions, amendments, motions, etc., were in English, French and German it was by no means an easy task to follow all details, although important items were interpreted by the several secretaries, Dr. Harms, of Berlin, in German, and Dr. Briquet, of Geneva, in French. During the first two days progress was relatively slow, but real progress was made on the third day by disposing of all the minor matters on a single motion, thus leaving time to consider the few really important and more or less controversial items. The proposed amendments of the International Code had to do largely with unifying, as far as possible, the divergences in this code and the so-called American Code.

Few formal votes were taken, most of the motions, after discussion, being disposed of by show of hands. In reference to important controversial matters the proportions of the vote as between yes and no were impressive. Thus, in reference to required Latin diagnoses for new species proposed from January, 1932, the formal vote was yes 371, no 24; the original spelling of generic and specific names was maintained by a vote of 342 to 21. An adoption of the rule, the contention of many American botanists, that a validly published homonym invalidates the use of the same specific name for another species was carried by yes 261, no 111; the adoption of the principle of types or standard species for genera and the confirmation and extension of the principle of *nomina generica conservanda* were carried by equally impressive majorities, the latter being practically unanimous. A proposition to make the year 1753 the begin-

ning date for binomials in all groups of plants was lost, the vote being 158 yes, 239 no.

One of the final actions of the section was to appoint a large international committee, having in its membership one or more representatives in each country, to consider interim problems in relation to the international rules, the details to be handled by a small executive committee. In addition to the appointment of the international committee to consider problems of nomenclature, other important committees were appointed, including one to standardize the terminology used in ecology; one to compile and publish an international botanical address book, and one to standardize descriptive terms used in systematic botany.

At the final plenary session of the congress, the invitation of the Netherlands to hold the next congress at Amsterdam in 1935 was accepted.

The Fifth International Botanical Congress was, unquestionably, the largest and most important gathering of its kind yet held. In excess of 50 countries were represented by about 1,200 official delegates. Naturally, Great Britain was particularly well represented, but there were about 300 delegates in attendance from the United States. Other important countries had large contingents, and most of the smaller commonwealths had representatives present. The congress was truly international in all respects, its attendance including many of the outstanding botanists of the entire world. The entire congress was pervaded by a pronounced spirit of international goodwill, which was particularly noticeable in the long and complicated discussions appertaining to the problems of nomenclature; here many divergent opinions were held, yet all present were inspired by the desire to facilitate the proceedings; each was willing to give and take; and all who took part in the discussions or who merely attended in order to familiarize themselves with the complicated questions under discussion were impressed with the desirability of coming to an understanding that would be truly international as well as acceptable to the majority of botanists in all fields of endeavor.

E. D. MERRILL

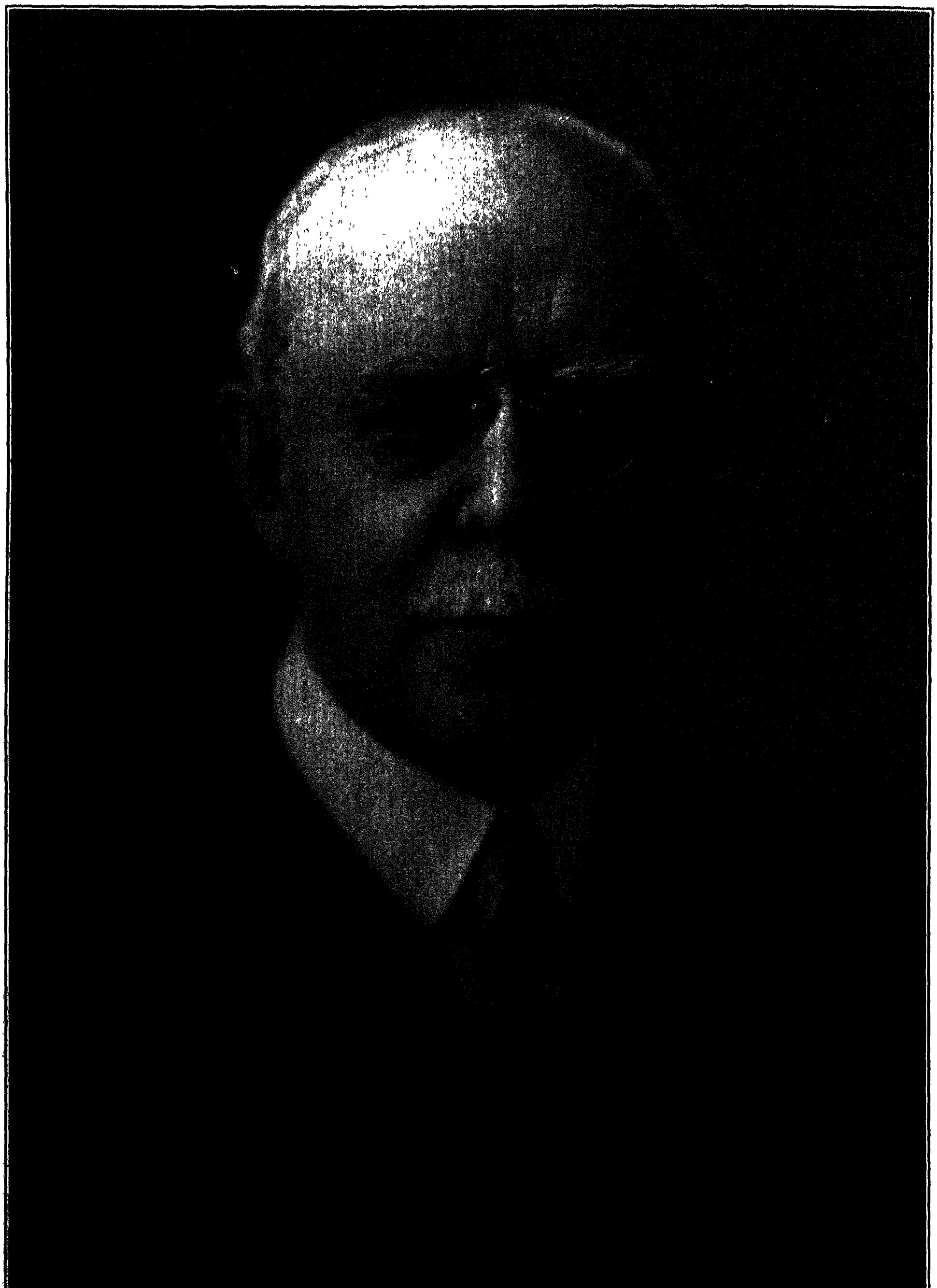
JOHN GEORGE HAGEN, S.J.

IN the quiet of the secluded little infirmary of the German College, Rome, Father John G. Hagen, S.J., piously passed to his eternal reward on the morning of September 6, 1930.

Father Hagen was born at Bergenz, Austria, March 6, 1847. Upon the completion of his early schooling, he entered the Society of Jesus and pursued his higher studies at Feldkirch, Münster and Bonn. Shortly after his ordination to the priesthood he came to the United States and was employed as professor of mathematics at Prairie du Chien, Wisconsin. Being appointed to the directorship of the Georgetown College Observatory, Washington, D. C., in 1888, he remained in this position until, in 1906, he was summoned by the Roman Pontiff, Pope Pius X, to take charge of the Vatican Observatory, Rome. With untiring devotion, increasingly difficult as his years advanced, he continued at this post until his last illness forced his retirement. Upon the occasion of his eightieth birthday, in 1927, the Holy Father, Pope Pius XI, had struck a gold medal and presented it to Father Hagen in recognition of distinguished service rendered in the field of astronomical research. Astronomy lost in the death of Father Hagen a splendid contributor and a tireless worker, and a wide circle of acquaintances a charming friend.

The "Atlas Stellarum Variabilium" may well be styled Father Hagen's lifework. Only those familiar with the study of variable stars can properly ap-

FATHER JOHN G. HAGEN, S.J.



DR. ARTHUR D. LITTLE

preciate the worth of this contribution. Zones + 55 to + 64 of the "Astrographic Catalogue" were completed at the Vatican Observatory, under Father Hagen's direction. Under the title "Die Veränderlichen Sterne" Father Hagen presented a historical survey of work done in the field of variable stars. During the last ten years of his life, he gave much time to the observation of cosmic clouds—especially stressing the 52 extended, diffused nebulosities of W. Herschel and Barnard's 349 dark objects. A long list of published articles splendidly evidences his wide interest and untiring zeal in his chosen profession.

Father Hagen was a member of the leading astronomical societies both here and abroad, and served, from the time of its establishment, on four of the commissions of the International Astronomical Union.

PAUL A. MCNALLY, S.J., *Director*,
Georgetown College Observatory

THE AWARD OF THE PERKIN MEDAL TO DR. LITTLE

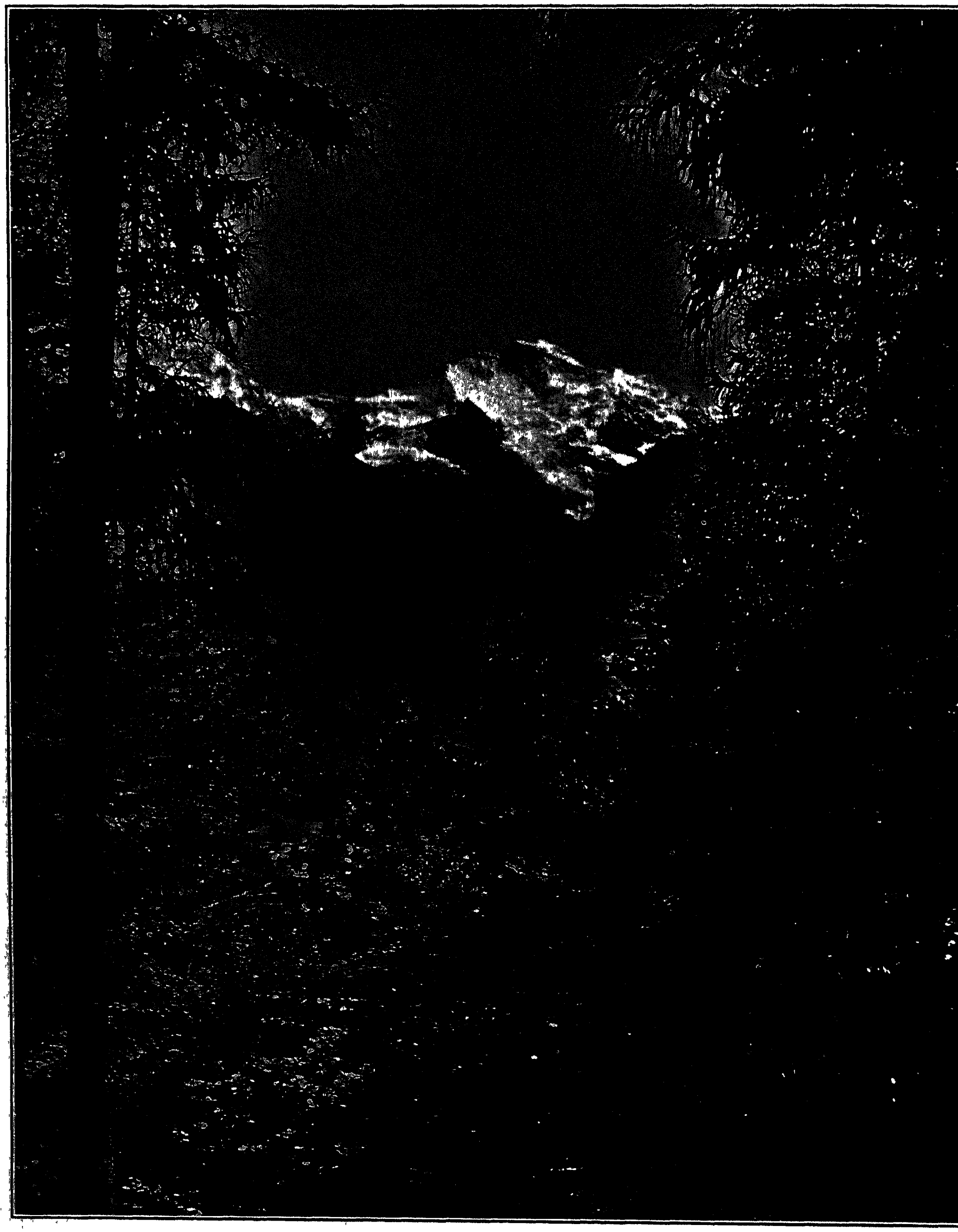
THE Perkin Medal for 1931 will be awarded early in January to Dr. Arthur D. Little, president of the chemical research and testing laboratories bearing the same name. This honor is conferred yearly upon a distinguished chemist on the basis of a life-time achievement in chemistry by the joint action of five chemical societies. The first medal was given to Sir William Perkin in 1906, and last year it was awarded to the late Dr. Herbert H. Dow. The five societies whose representatives select the recipient are: Society of Chemical Industry, American Chemical Society, American Electrical Society, American Institute of Chemical Engineers and the Société de Chimie Industrielle.

Dr. Little is past president of the American Chemical Society, of the American Institute of Chemical Engineers and of the Society of Chemical Industry. In the latter capacity he presided at the annual general meeting of the society at Manchester, England, in 1929, at which time the University of Manchester conferred on him the honorary degree of doctor of science and the Manchester College of Technology made him an honorary associate.

Dr. Little has worked extensively in the field of the application of chemistry to industry. He is the inventor of processes for the manufacture of chrome-tanned leather, chlorate of potash, cellulose acetate, smoke filters, newsprint from Southern woods, as well as others dealing with the recovery of naval stores from lumbering wastes and vapor-phase cracking of petroleum. He has made a specialty of the chemistry of cellulose fibers and paper-making, and of gas and petroleum.

In 1922, as chairman of a committee of the American Institute of Chemical Engineers, he made a thorough study of courses of chemical engineering in American institutions of learning and prepared an extensive report covering his findings. He has at all times maintained that the training of chemical engineers should be broad and cultural, as well as technical, if they are to be fully equipped to reach their highest development personally as well as professionally.

Dr. Little has been untiring in his endeavors to place chemistry on a par with the other recognized professions and he has unceasingly urged upon the practitioners of chemistry the importance of upholding the profession and of maintaining for themselves a proper place in the community. He is able to translate the findings of chemistry to the layman in a clear and readable style, and he has used this gift unstintingly in the service of chemistry. From the beginning of his career he has been one of the country's effective exponents of research, and he has helped in no small measure to bring about the better appreciation of the creative power of research which has come in recent years.



THE JUNGFRAU AS SEEN FROM INTERLAKEN

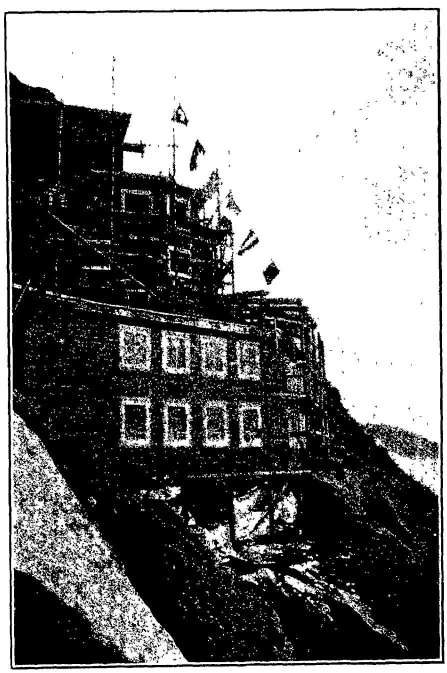
A SCENE ON TOP OF THE JUNGFRAU

SHOWING THE OLD METEOROLOGICAL PAVILION AND THE MASSIVE SNOW BANKS.

THE HIGH ALTITUDE INSTITUTE ON THE JUNGFRAU

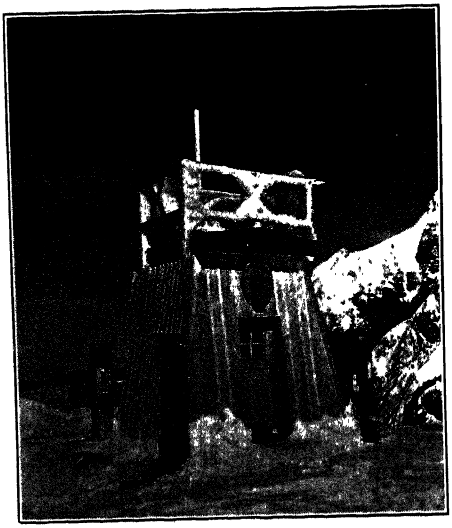
A NUMBER of organizations have cooperated in bringing to fruition plans for the Jungfrau High Altitude Institute (Institut für Höhenforschung auf dem Jungfraujoch) in Switzerland. The building of the Jungfrau railroad made possible access by tunnel at all seasons of the year to a mountainous area at a height of 3,500 meters. A site on the Jungfrau in the vicinity of the railway terminus was chosen for the scientific institute where investigators in the field of astronomy, botany, geology, meteorology, glaciology, hydrology, physics, physiology and biology will have facilities for pursuing individual investigations.

In addition to support from the Cantonal Government, the Jungfrau Railway and other local sources, aid toward this project was obtained from such varied international sources as the Kaiser Wilhelm Society, the Royal Society of London, the Academy of Sciences of Vienna, the University of Paris and the International Education Board.



THE JUNGFRAU HIGH ALTITUDE INSTITUTE

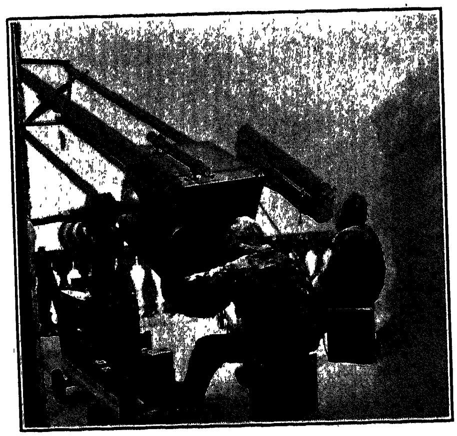
UNDER CONSTRUCTION IN SWITZERLAND.



THE OLD METEOROLOGICAL PAVILION

The latter organization authorized a contribution for this purpose in 1928. It is understood that the University of Geneva expects to erect a small astronomical observatory in the vicinity.

The development of the institute has been under the control of a committee of the Swiss Society of Natural Sciences and of the Kaiser Wilhelm Society, under the presidency of Professor W. R. Hess. A board of directors is elected from the membership of the Swiss Society of Natural Sciences and forms the administering body. The use of the station is available to scientists of all nationalities. It will provide facilities for work in the natural sciences with problems whose solution depends upon experimental observations made at a high altitude. It is realized that research in the natural sciences requires easy and sure connections with the rest of the world. In the new building modest but adequate facilities for many-sided activities will be available throughout the year.



ASTRONOMERS AT WORK

ASTRONOMICAL OBSERVATIONS ARE REGULARLY MADE ON THE MOUNTAIN TOP.

The Berghaus Jungfraujoch on the summit has the distinction of being at a higher altitude than any hotel in Europe. Easily accessible by electric mountain railway, the Jungfrau has become throughout the year a playground for lovers of snow sports. The establishment of the new institute will provide an added interest to tourists.

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